Hydrobiology

WILSONS RIVER REACH AUDIT AND PLANNING: ELTHAM TO BOATHARBOUR

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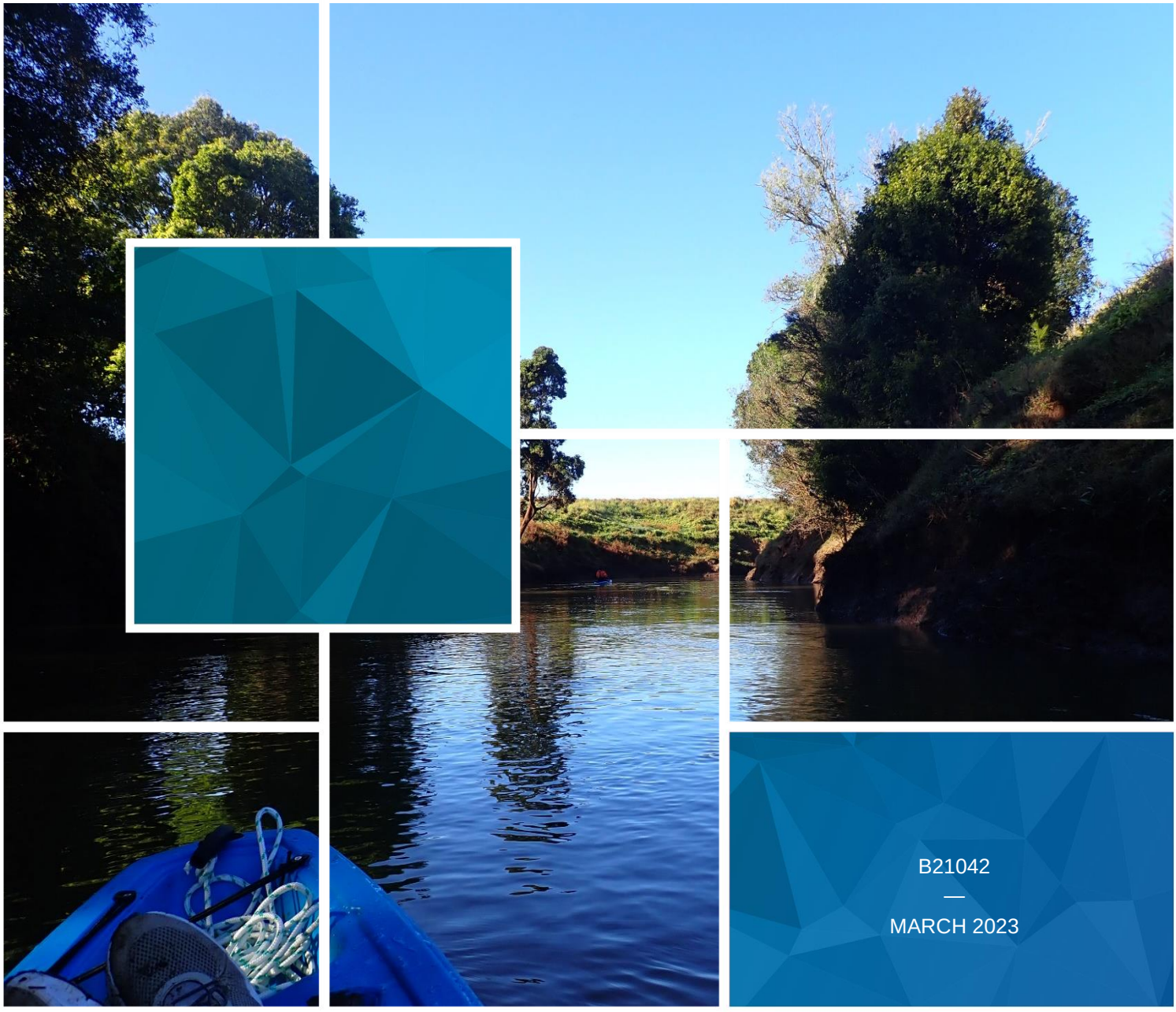
PART B: REACH SCALE ASSESSMENT OF CONDITION AND REACH PRIORITISATION



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EXECUTIVE SUMMARY

This report uses a multidisciplinary approach to conduct Part B of the scope to the Wilsons River – River Audit and Planning Project, undertaking a reach-scale assessment of condition to inform reach-based prioritisation to guide future site and property-based management initiatives.

Wilsons River is a perennial river that is part of the Richmond River catchment in northern NSW. The River Reach Program 2011 is an initiative by Rous County Council to manage the threats to ecological integrity and water quality within the Wilsons River through targeted river reach-based management. This document aims to develop a new River Reach Plan for the middle extent of the Wilsons River, located between Eltham and the Boat Harbour Nature Reserve ('study reach'), by conducting a condition assessment to determine priority reaches and management actions. This study incorporates all aspects of aquatic/riparian ecology, geomorphology, hydrology, water and sediment quality, and stakeholder engagement.

Part B of the project to develop a river reach plan for Boat Harbour to Eltham incorporated a number of stages of approach, as per the SoW. These included:

- **Task B1 – Complete Project Planning**
- **Task B2 – Reach Scale Assessment of Condition**
- **Task B3 – Reach-Based Rehabilitation Plan**
- **Task B4 – Property Based Rehabilitation Plans (Future works)**

The approach involved several tasks, including several desktop and field components that incorporated both ecology and geomorphology, listed below and described in Section 2:

- ***Desktop assessment***
- ***Initial Characterisation***
- ***Reach Breakdown***
- ***Field Visit***
- ***Landholder Interaction***

These were incorporated to assess the relative condition of sub reaches and determine priority management needs to create a reach based plan.

In general, the results found that the upper sub-reaches of the study reach were more impacted by the recent February 2022 floods, affecting both the current geomorphic and ecological condition. This was mostly due to the upper sub-reaches having undergone headcut migration, channel incision and widening, due to a meander cut-off in Sub-Reach 8, with the migration of headcuts upstream of this accelerated by the floods. As a result, less incision was observed downstream, however there was also a lack on instream habitat observed in Sub-Reach 9 and Sub-Reach 12-17.

The priority sub-reaches for management were identified as Sub-Reach 1, 4, 5-9 and 13-17, with overlap with interested property owners shown in Figure 3-28. Sub-Reach 5-9 management issues were mostly geomorphic such as major bank erosion, headcut migration, channel incision, widening and avulsion risk; while Sub-Reach 9, and 13 – 17, also had some geomorphic issues, greater management needs were identified for instream habitat condition. Another priority issue identified is the mapped headward eroding gullies and tributaries that are adjusting to the new incised base level of the Wilsons River channel, which were noted during the site visit as being a major in-stream sediment source. These are occurring in Sub-Reaches 1, 3, 6/7, 8, 10-13, 18, and 19 and will require catchment management focus in addition to riverine management actions.

A summary of the issues within each of these priority sub-reaches are as follows:

- **Sub-Reach 1:**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
    - Headcuts/Incision.
    - Potential avulsion location.
  - Habitat issues:
    - Moderate lack of instream structure provided by woody debris.
  - Bank Vegetative Stability:
    - A moderate level of bank stability provided by Lomandra.
- **Sub-Reach 3:**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
- **Sub-Reach 4:**
  - Geomorphic Issues:
    - Incision.
    - Widening.
  - Habitat issues:

  - Lacking some habitat diversity, however the large amount of woody debris present provides considerable in-stream structure.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra, poor riparian cover and dominant exotic species.

- **Sub-Reach 5 to Sub-Reach 8:**
  - Geomorphic Issues:
    - Major erosion and bank exposures at bends.
    - Widening.
    - Potential headcuts, with point of upstream incision from Sub-Reach 8.
    - Incision.
    - High avulsion risk.
    - Headward eroding/perched gullies draining poorly vegetated catchments.
  - Habitat issues:
    - Lacking some habitat diversity, however the large amount of woody debris present provides considerable in-stream structure, except for Sub-Reach 8 that lacks woody debris.
  - Bank vegetative stability issues:
    - Moderate bank stability provided by Lomandra, with the exception of Sub-Reach 8 that has a low level of bank stability due to a lack of Lomandra.
    - Lack of continuous riparian zone and high presence of weeds.
- **Sub-Reach 9:**
  - Geomorphic issues:
    - Poor condition / Lack of habitat diversity / No riparian cover.
    - Bank slumping and scour.
  - Habitat issues:
    - Lack of habitat diversity and little LWD, poor in-stream habitat.
  - Bank vegetative stability issues:
    - Low level of bank stability due to a lack of Lomandra. No riparian habitat.
    - Prominence of weed species in a highly disturbed riparian zone.
- **Sub-Reach 10-11**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
- **Sub-Reach 12:**
  - Geomorphic issues:
    - Potential headcuts.
    - Scour.
    - Headward eroding gullies draining poorly vegetated catchments.
  - Habitat issues:
    - Moderate lack of instream structure provided by woody debris.
  - Bank vegetative stability issues:
    - Poor bank stability due to a lack of Lomandra.
    - Poor riparian condition, including weed dominance.

- **Sub-Reach 13 – 17:**
  - Geomorphic issues:
    - Minor incision.
    - Scour.
    - Lack of habitat.
  - Habitat issues:
    - Poor habitat diversity and a general lack of instream structure provided by woody debris.
  - Bank vegetative stability issues:
    - Poor bank stability due to a lack of Lomandra and significant riparian clearance, except for Sub-Reach 16 and 17.
- **Sub-Reach 18-19**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
- **General issues related to mapped gullies/tributaries (locations described above):**
  - Issues:
    - Headward eroding and incision.
    - Produce large sediment (fine and coarse) source to main Wilsons River.
    - Affect water quality and habitat.
    - Degradation of upstream catchment and loss of farming land.

A summary of each of the issues throughout the study reach, associated recommendations, and sub-reach prioritisation are summarised in Table 4 1 in Section 4 of this report. This forms part of Stage B of the River Reach Plan. The next steps of this work will be to generate site-based plans with property owners for each of the priority sub-reaches highlighted in this study, which will be provided in subsequent reporting. In addition to the issues raised in this scope of works, River Style mapping of condition and recovery potential for the Wilsons River catchment suggests that future works could focus on upstream reaches of Wilsons River and its tributaries.

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1. INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES

Wilsons River is a perennial river that is part of the Richmond River catchment in northern NSW. The River Reach Program 2011 is an initiative by Rous County Council (RCC) to manage the threats to ecological integrity and water quality within the Wilsons River through targeted river reach-based management. These are long-term strategies that aim to continually improve water quality within the Wilsons River and surrounding catchment areas by improving riparian vegetation and reducing impact from catchment land use and degradation. Hydrobiology has recognised the importance of catchment condition on riverine water quality both within Wilsons River catchment and further afield in previous studies. As such, appropriate attention will be focused on both fluvial and catchment sources and management measures to control these.

Hydrobiology understood that RCC required a contractor to conduct environmental services for the following objectives:

- ***Part A –*** *Review work completed as part of the Wilsons River Source River Reach Plan since 2011.*
- ***Part B –*** *Develop a new River Reach Plan for the middle extent of the Wilsons River, located between the Boat Harbour Nature Reserve and Eltham.*

Given the above objectives, it is our understanding that the project will require a diverse multidisciplinary team that addresses all components of:

- Geomorphology (i.e., bank and bed stability, active processes such as incision, erosion, scour etc.).
- Riparian health (in-stream and bank vegetation, weeds, grazing impact, etc).
- Water and sediment quality.

- Hydrology in consideration of channel and sub catchment condition (i.e., flow timing, rates of run off, detention, magnitude, frequency).
- Sub-reach and tributary sub catchment management prioritisation.
- Stakeholder engagement, including initial liaison and subsequent workshops with landholders.

This report uses a multidisciplinary approach to conduct Part B of the scope to the Wilsons River – River Audit and Planning Project (Figure 1-1). This document develops a new River Reach Plan for the middle extent of the Wilsons River, located between Eltham and the Boat harbour Nature Reserve ('study reach'/'project reach'), by conducting a condition assessment to determine priority sub-reaches and tributary catchments for management. This study incorporates all aspects listed above. The methods have been specifically selected to target the main objectives of RCC's catchment plans, including:

- Protection of Wilsons River water quality and aquatic habitat.
- Improvement to agricultural productivity.
- Increased biodiversity and ecological linkages between Boat Harbour Nature Reserve and other parts of the catchment.

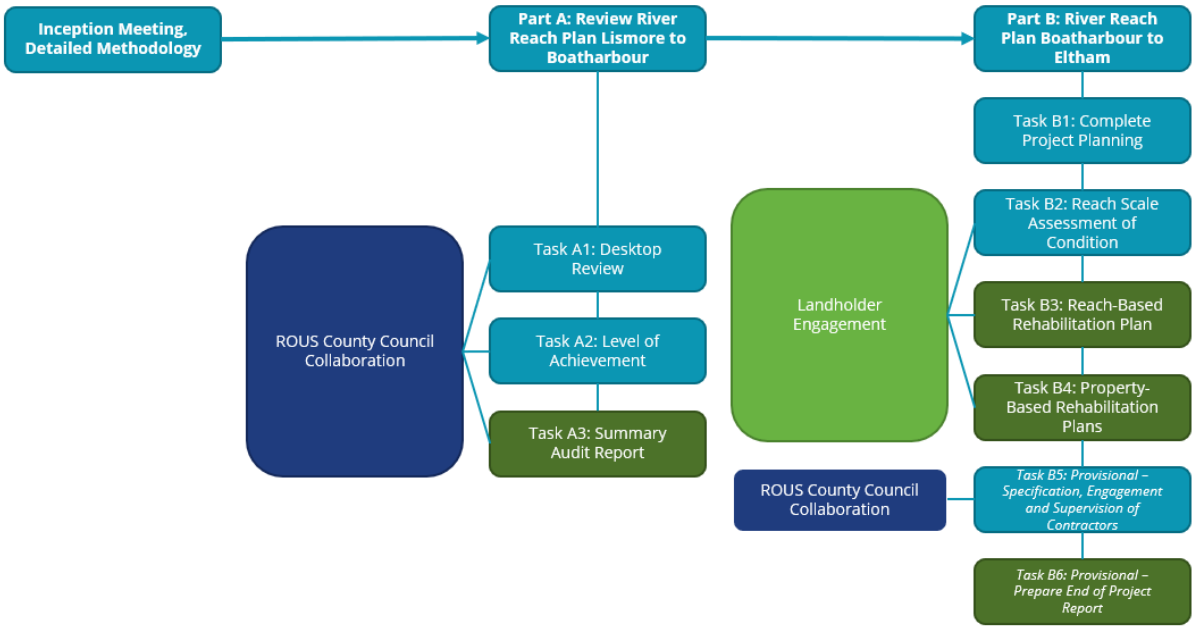


Figure 1-1 Program flowchart.

1.2 DETAILED SCOPE APPROACH

1.2.1 GENERAL

Part B of the project to develop a river reach plan for the study reach incorporated several stages of approach, as per the SoW. These included:

- Task B1 – Complete Project Planning.
- Task B2 – Reach Scale Assessment of Condition.
- Task B3 – Reach-Based Rehabilitation Plan.
- Task B4 – Property Based Rehabilitation Plans (future works).

These tasks are outlined in the following sections.

1.2.2 TASK B1: COMPLETE PROJECT PLANNING

Identification of relevant stakeholders

While not listed specifically in the SoW, this step was an important part of the process to ensure all interested parties were identified prior to the beginning of works. Inclusion of inputs from all relevant stakeholders is key to ensuring outcomes are successfully implemented and maintained in the long term. Landholders, Boat Harbour Landcare Group, and RCC are the three main stakeholders but a review and liaison with RCC identified additional property owners.

Review background information

Hydrobiology's ecologists and geomorphologists reviewed the relevant data and literature listed in the SoW. Hydrobiology also sourced relevant aerial imagery, Lidar, and other spatial datasets, and interviewed relevant stakeholders (where applicable) to provide a greater understanding of the catchment and study reach. Jim Tait provided excellent local experience/understanding of the catchment.

To ensure the review identified relevant issues, a review template was developed so that each reviewer is guided through the process in the same way. In addition to the data provided in the SoW, Hydrobiology's review included those items listed in the previous Task A, including:

- Relevant case studies.
- Catchment land use and condition to understand sediment and contaminant load source inputs.
- State and national matters of environmental significance relevant to aquatic and riparian systems.
- Rehabilitation and recovery plans for any identified state and national environmental matters.
- Major water quality issues for the study reach and catchment, including guideline values. This included a review of all water quality monitoring data that were available.

Refine Methodology and Seek Approval from RCC

Early in the process Hydrobiology engaged RCC with regard to the approach provided to allow for a discussion regarding the gaps, opportunities, and strengths of the proposed approach and allowed for a *codesign* approach to the final methodology.

Contact Property Holders

In collaboration with RCC, wording was drafted to be inserted into a RCC letter to riparian landholders that included the following:

- Purpose of works.
- Broad approach.
- Proposed ongoing engagement (e.g., in-person meeting, workshop).
- Field visit timing.
- Request for involvement to obtain the different landholders' level of interest in being involved in the project (including Site Action Plans).
- Requested input with regard to potential catchment/river/creek/gully issues that are present on, or adjacent to, their property.

1.2.3 TASK B2: REACH SCALE ASSESSMENT OF CONDITION

The methodology listed in the SoW was followed to ensure it met all RCC requirements. Hydrobiology also undertook a number of additional items to ensure that the condition of the study area was accurately represented across the different encountered reaches. This included a number of desktop and field components, outlined below and described in Section 2:

- *Initial Characterisation.*

- *Reach Breakdown.*
- *Field Visit.*
- *Landholder Interaction.*

1.2.4 TASK B3: REACH-BASED REHABILITATION PLAN

Reach-Based Prioritisation

The results from the desktop and field components were used to initially develop a reach-based condition assessment of the study reach and a catchment-based condition assessment of the tributaries and gullies feeding into the river. From this initial condition assessment, a weighted sensitivity analysis was undertaken to develop reach prioritisation that considered the following:

- Geomorphic sensitivity and recovery potential, as mapped by NSW River Styles mapping.
- Updates/improved resolution of geomorphic sensitivity and recovery mapping undertaken during the desktop and field-based components of the project.
- Riparian recovery potential based on weed and native vegetation presence/ratio, native vegetation recruitment, etc.
- Tributary catchment condition assessments.
- Presence/absence of State or National Matters of Environmental Significance.
- Aquatic habitat, condition, and services, including water quality.
- Landholder interest.
- Boat Harbour Landcare Group reach rating and grant availability. During our liaison with the group, their prioritisation recommendations were incorporated in management assessments.
- Availability of RCC funding.
- An informal workshop was held with the Hydrobiology team, RCC, and Boat Harbour Landcare Group to discuss and refine the prioritisation.

This approach of this task is detailed further in Section 2.

Site-Based Planning

As part of the above process, reach- and site-specific treatment options were identified as outcomes from this document and will be incorporated into the next reporting stage. These may include those listed in the SoW and others, such as:

- Physical bed remediation (i.e., headcut treatment options).
- Avulsion prevention (e.g., increased floodplain roughness, bank remediation, etc.).
- In-stream habitat improvements (e.g., LWD, fish 'hotels').
- Gully stabilisation.
- Promotion of enhanced detention function (including basins) within tributary catchments.
- Revegetation of main channel and tributary catchment riparian zones and wetland basins.

This will include engagement with landholders, including a series of workshops following the reach prioritisation from this document to discuss reaches and potential site-based action plans.

1.2.5 TASK B4: PROPERTY-BASED REHABILITATION PLANS (FUTURE WORKS)

Property based rehabilitation plans will be developed in subsequent reporting to this document as the next stage in this project, with landholders in focal management areas who have expressed a willingness to engage with the project. The process will involve:

- Initial plan development by Hydrobiology based on the reach and tributary catchment condition and prioritisation assessment. This is based on both the desktop and field assessment described above and the initial feedback from each landholder in the survey and workshops.
- 2-hour workshop with each landholder to discuss their perceived issues. These will be mapped and compared with the initial plan.
- The plan will be refined during the workshop, based on both the above inputs.
- Each site-based plan will be developed with consideration of:
  - Zonation of each property based on geomorphology, ecology, land use and vegetation cover.
  - Weed presence (canopy, understorey).
  - Vegetation cover/density and corridor width.
  - Grazing/land use issues.
  - Feature of high ecological / nature conservation value including catchment /regional habitat connectivity.
  - Regeneration opportunities.
  - Geomorphological issues, including:
    - Drainage patterns.
    - Bed/bank stability (erosion/aggradation).
    - Headcuts.
    - Avulsion risk.
    - Gullying.
  - Physical and biotic aquatic habitat.
  - Water quality drivers including flow behaviour and contaminant source loads.
  - Hydraulic hotspots where issues may develop in the future.
- Site-based plans for riverine environments will be mapped as per the SoW, with the following alterations:
  - Additional zones developed for catchment/floodplain issues (e.g., avulsion pathways, gullying, etc.).
  - Hydraulic and geomorphic hotspots will be indicated using point-files similar to the “erosion issue” stars in the NRCMA approach.
  - Underlying the zonation, aerial imagery will be draped over Lidar to illustrate topographic change more effectively.
  - If available, hydraulic modelling outputs will also be shown in a separate map to show where the hotspots lie.

2. APPROACH

2.1 TASK B2: REACH SCALE ASSESSMENT OF CONDITION

2.1.1 SUB-REACH BREAKDOWN

Following the review of the River Reach Plan and the initial characterization based on the NSW Government state-wide River Styles database, the study reach was further divided into representative reaches for the field-based assessment of condition. The study reach was divided into sub-reaches using satellite imagery and available Nearmap imagery. The imagery was assessed visually to identify distinctions in vegetation, land use, channel confinement, and sinuosity along the study reach to divide the study reach into definable sub-reaches. The final sub-reach breakdown is presented in Section 3.

2.1.2 FIELD VISIT

2.1.2.1 GENERAL

The field visit comprised an initial reconnaissance trip on 20th – 22nd June 2022, followed by the main assessment of condition on 5th – 9th September. The main purpose of the field assessment was to undertake a reach-based assessment of condition, to prioritise sub-reaches for rehabilitation site-based plans and to form a baseline against which to assess success/level of achievement of future works. The site visit involved two teams: one undertaking a kayak-based assessment of reach geomorphic and ecological condition, and the second involving meetings/workshops with RCC, Boat Harbour Landcare Group, and landholders. The methods for each field component are described in the following sections.

2.1.2.2 GEOMORPHOLOGY

The geomorphic condition assessment (including channel stability, erosion, scour and incision present) was carried out using a modified River Styles Stage 2 Geomorphic Condition (Brierley and Fryirs, 2005, 2013) and Simon, (1989) & Simon *et al.*, (2007) field proforma to assess geomorphic condition. The field proforma used in this study are outlined in Appendix A. These proforma were used to identify current condition, stage of river evolution, sensitivity to change and recovery potential. In addition to the proforma, macro and micro-geomorphic and habitat features, and geomorphic processes were identified and geolocated using AvenzaMaps software, including but not limited to:

- Bed and bank erosion extent and severity.
- Avulsion risk (e.g., meander bend cut-off).
- Headcut locations.
- Depositional areas.
- Riparian vegetation density.
- Gullying.

2.1.2.3 ECOLOGY

The full methodology implemented for habitat and water quality assessments, forming the ecological condition assessment can be found in Appendix B.

2.1.2.4 DRONE

During the field visit, a DJI Mavic Pro drone was deployed to capture aerial imagery of each of the sub-reaches where possible. Due to time constraints and limited property access, only Sub-Reaches 1-7, Sub-Reaches 13-14 and Sub-Reach 19 were flown. Captured imagery was used to generate ortho-mosaic coverage used alongside Nearmap imagery in the mapping analysis and will be used as part of the future site-based plans. The UAV was flown at altitudes ranging from 60 to 120 m (depending on the heights of the surrounding vegetation and valley walls) from the starting point of each of the surveys. The flight planning accounted for a minimum overlap of 65% in the flight direction and a minimum overlap of 60% for the side strips using the Drone Deploy flight app processing software for an automated flight path to ensure sufficient coverage. DroneDeploy's AI powered cloud processing software was used to generate ortho-mosaics from the UAV surveys. Since no Ground Control Points were used (outside of scope), the RMSE georeferencing error of the ortho-mosaics equated on average to 1-2 m.

2.1.3 LANDOWNER ENGAGEMENT

As outlined above, several meetings/workshops were held on 5th – 7th September 2022, including:

- Meetings with landholders discussing on-site issues. Jim Tait and Ben Pearson attended these.
- Workshop with RCC and Boat Harbour Landcare Group. Large aerial print outs were presented to identify areas of interest/concern and to discuss any issues both on the Wilsons River study reach and their properties. This was used in conjunction with the field visit to guide desktop assessment and help identify priority areas for management.

2.1.4 DESKTOP ASSESSMENT

Following the field visit and the landowner engagement, the above assessments were input into mapping of condition in ArcGIS Pro, both from a geomorphic and ecological perspective, as well as issues identified from the workshop session. In terms of geomorphology, geomorphic condition was ranked and mapped based on the field proforma for each of the sub-reaches. GPS locations of major erosion areas, potential avulsion, headcuts and eroding gullies/tributaries were mapped, and used to

produce an Erosion Severity ranking for each of the sub-reaches. Methodology for mapping of ecology metrics is outlined in Appendix B.

2.1.5 GULLIES AND TRIBUTARIES

Catchment sources were identified as potentially a major source of sediment to Wilsons River. Section 3.1.2 noted that considerable sheet flow, mass movements, and rill/gully erosion had occurred throughout the catchment and, specifically in upstream catchment areas and in sub-catchments draining directly into the study reach. As such, while not entirely considered as part of the study area, contributing sources of sediment were investigated during the desktop and field assessment. A total of 18 gullies/tributaries were identified as flowing into the study reach. Many of these gullies were observed to experiencing several geomorphic issues that are currently responsible for increased sediment inputs into the study reach, including:

- Main channel incision forcing perched gully bed levels at their confluence.
- Headward eroding knickpoints/headcuts that have resulted in gully expansion (deepening, widening) and increased gully network.
- Large catchments with the potential to contribute large volumes of sediment.
- Poor riparian/gully and catchment vegetation as a result of landuses (Section 3.1.2) increasing likelihood of sedimented runoff.

All 18 gullies identified were assessed according to a rating system (Low/Moderate/High risk) based on the above issues, notably:

- Invert characteristics (i.e., perched confluence, active headcuts through length).
- Erosion/stability (i.e., is there obvious deepening/widening of the gully and its network).
- Vegetation cover (i.e., how well vegetated is the length of the gully).
- Catchment size.

The ratings were then used in the sub-reach assessment to identify gully issues and to guide potential management actions.

2.2 TASK B3: REACH BASED PRIORITISATION AND REACH PLAN

Results of the mapping analysis, in addition to field observations and outcomes from the landowner engagement were used to summarize issues in each sub-reach and to select sub-reaches for management prioritization. This was based on those sub-reaches that had a combination of major geomorphic issues (e.g., bank erosion, avulsion risk, headcuts), lower geomorphic condition rankings, lower riparian coverage and lower habitat rankings (e.g., lower bioassessment score, less instream habitat, less woody debris, lower Lomandra coverage).

From this, key issues in the study reach were summarized and recommendations provided for each issue, along with sub-reach locations of where management and rehabilitation should be prioritised. This will inform site-based reach plans (Task B4) for properties as part future works.

3. RESULTS

3.1 GENERAL CATCHMENT REVIEW

3.1.1 GENERAL

This section was included as part of the Part A reporting and is included herein to ensure the scope has been addressed.

3.1.2 LANDUSE AND EROSION

Land use groupings from the NSW's Richmond catchment multi-attribute layer for the Wilsons River Catchment are shown in Figure 3-1. The major land uses within the catchment are pasture, agriculture, and plantations. Other land uses include urban centres as well as residential and rural housing. Native forest is limited to National Parks and conservation areas. Large areas converted to farming are likely a major source of sediment within the catchment, depending on slope and erosion processes.

Slope groupings from the same layer for the Wilsons River Catchment are mapped in Figure 3-2. For the Combined Study Reach, the slope is low to very gently inclined (0 – 2%) along the partly confined floodplains. This is similar for the Coopers Creek tributary. However, the rest of the catchment is dominated by much steeper hillslopes and undulating terrain, ranging from 5-10% (undulating) to 50% (mountainous/precipitous). These steeper hillslopes are likely sensitive to erosion, given their lack of forest cover, and are a likely a sediment source, with high connectivity to river networks due to the confined nature of the catchment.

Erosion mapping from the NSW's Richmond catchment multi-attribute layer for the Wilsons River Catchment is shown in Figure 3-3 Most erosion within the catchment is limited to hillslopes rather

than riverine sources, suggesting that these areas form a large sediment source contribution to the river network and the Combined Study Reach. The main types of erosion include moderate sheet and rill erosion, as well as mass movement on unvegetated hillslopes.

3.1.3 RIVER CHARACTERISATION

River Styles from the NSW's database for the Wilson's River Catchment are shown in Figure 3-4. The Combined Study Reach was characterised as partly confined, planform controlled, low sinuosity gravel bed channels. The river has room to adjust within the partly confined valley but is relatively stable, constrained in sections by bedrock margin control (abutting <50%) and cohesive banks with low to medium sinuosity planform. Most rivers and streams of the upper Wilsons River Catchment are styles in confined valleys, consisting of gorge and headwater types or those with only occasional floodplain pockets. These styles have limited capacity to adjust laterally, but their steeper gradients and hillslope connectivity form a sediment source to the Wilsons River. The main tributary that joins the Combined Study Reach, Coopers Creek, is a laterally unconfined meandering gravel bed style with greater capacity for lateral adjustment and erosion. This branch also has partly confined planform-controlled gravel bed mid-catchment reaches with capacity for adjustment, forming a sediment source to Wilsons Reach.

Stream geomorphic condition from the NSW's River Styles database for the Wilsons Catchment is shown in Figure 3-5. River Styles are ranked in Good, Moderate or Poor condition. Reaches considered in good condition are those whose geomorphic river character and behaviour are appropriate for the River Style given its catchment position, while those considered in poor condition have geomorphic character and behaviour that are divergent from the natural reference condition. The Combined Study Reach was mapped as being in Moderate geomorphic condition. A large proportion of the catchment and tributaries draining into the reach were also mapped as being in Moderate geomorphic condition. Much of the Coopers Creek sub-catchment that drains directly into the Combined Study Reach was mapped as being in Poor condition. Only a few reaches within the national park or conservation area were mapped as being in Good geomorphic condition. The widespread poor to moderate condition of the catchment likely has a large influence on the condition of the Combined Study Reach.

River fragility from the NSW's River Styles Database for the Wilsons River Catchment is shown in Figure 3-6. A River Style's inherent fragility is its sensitivity to change based on its character, behaviour, and capacity for adjustment. Fragility is defined as the propensity of a river channel to change shape, location or condition when disturbed (geomorphic sensitivity), with fragility rated as High, Moderate, or Low. Most of the partly confined reaches in the catchment were classed as being moderately fragile, with high fragility limited to the laterally unconfined reach on Coopers Creek. Most of the confined upper catchment were considered to have low fragility. The Combined Study Reach was mapped as moderate fragility, suggesting it has some sensitivity to disturbance and change.

River recovery potential from the NSW's River Styles Database for the Wilsons River Catchment is shown in Figure 3-7. The Wilsons Reach was mapped as having Moderate recovery potential, meaning that its recovery is limited by its position in the catchment and is downstream of poor or moderate condition reaches that have the potential to impact the condition of the reach. Recovery can be enhanced only if upstream reaches are rehabilitated. The River Style framework recommends prioritizing other reaches, and to rehabilitate upstream reaches first. Most of the catchment is mapped as having moderate recovery potential, with conservation, rapid and high recovery potential reaches limited to the upper catchment within or near the national park or conservation areas. This suggests that lower catchment reaches such as the Wilsons Reach are unlikely to be successful in rehabilitation without consideration for improvements to the catchment slopes and reaches upstream of the Combined Study Reach.

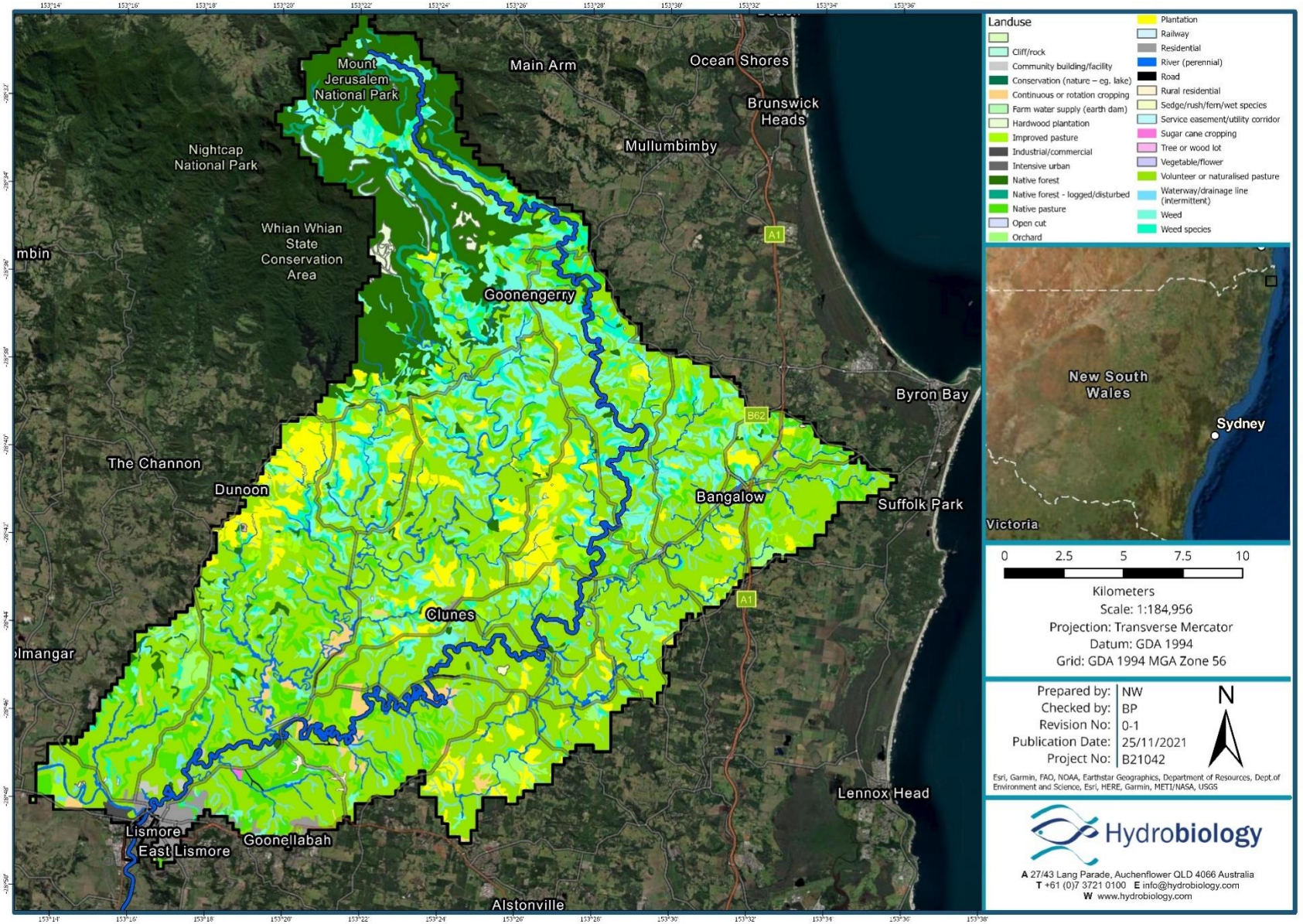


Figure 3-1 Land use groupings within the Wilson's River Catchment.

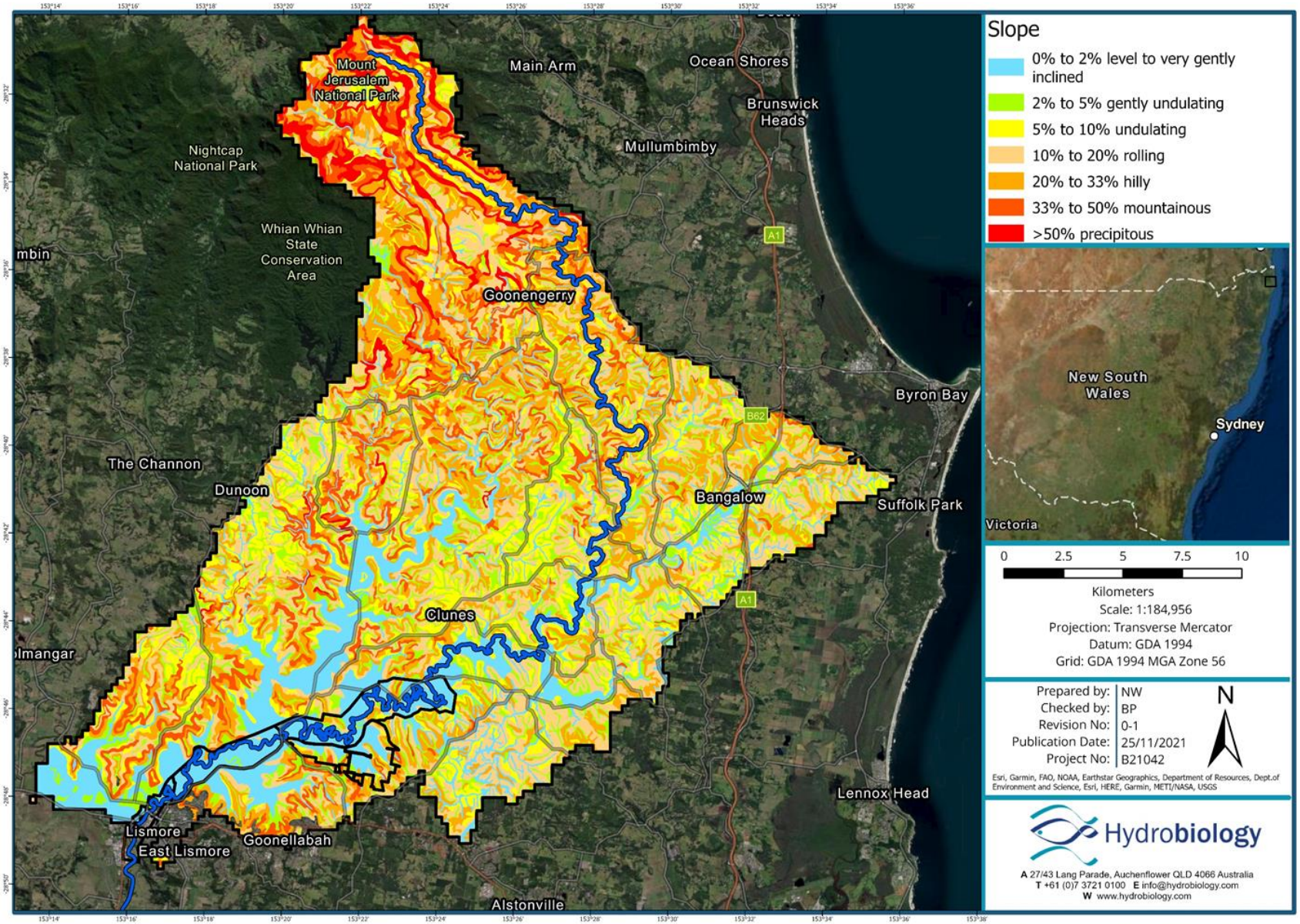


Figure 3-2 Slope groupings within the Wilsons River Catchment.

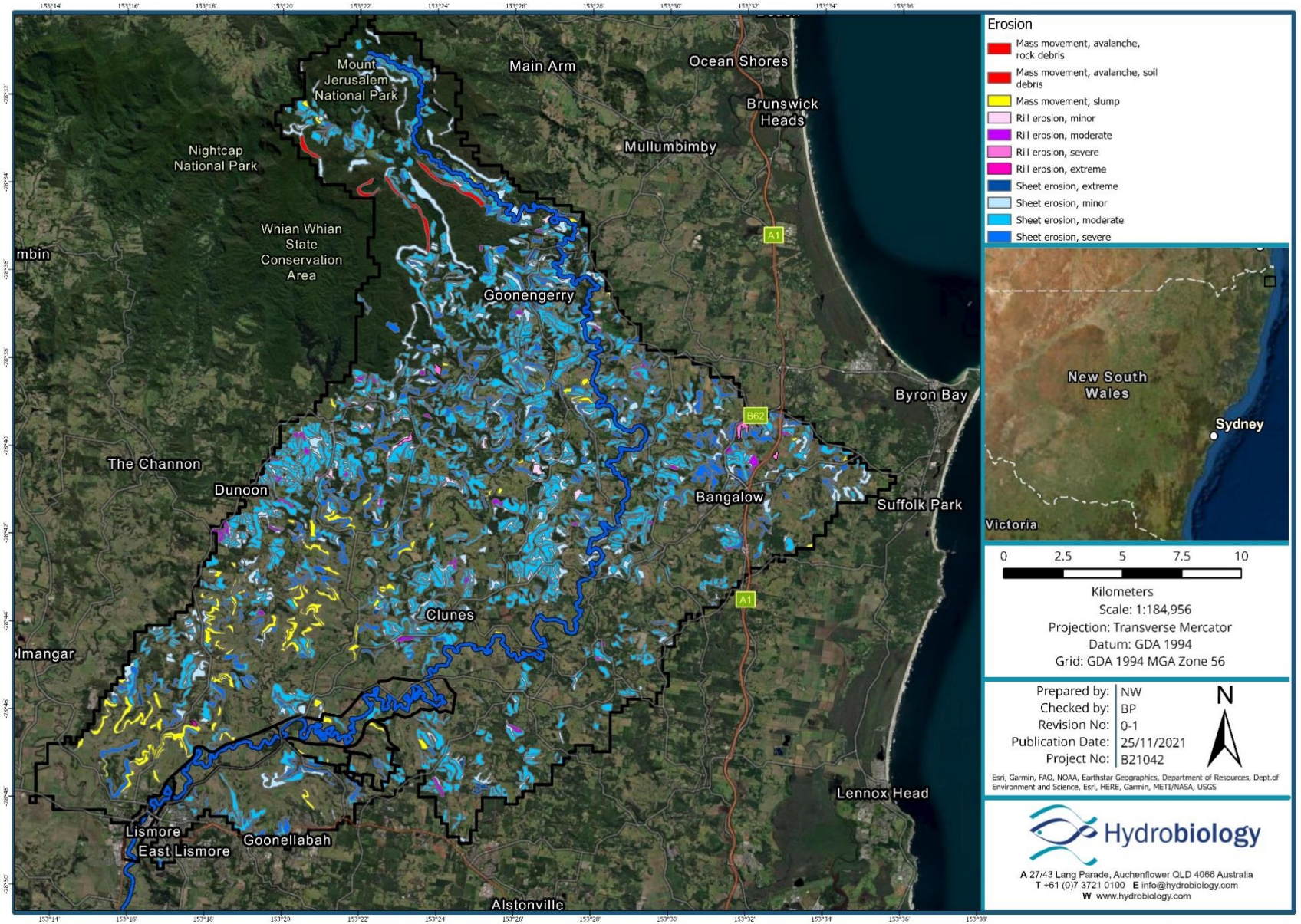


Figure 3-3 Erosion mapping within the Wilsons River Catchment.

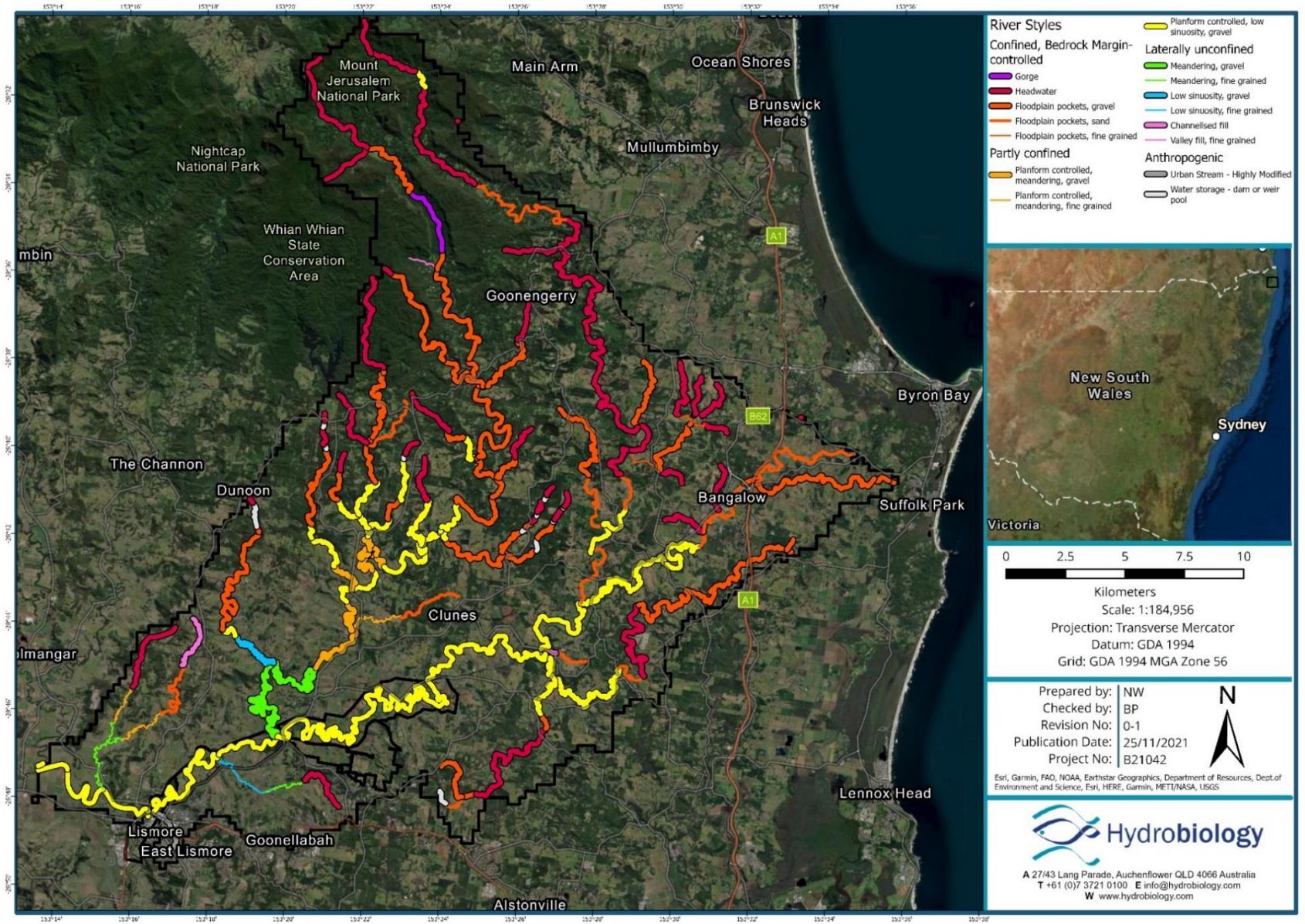


Figure 3-4 NSW River Styles mapping of the Wilsons River Catchment.

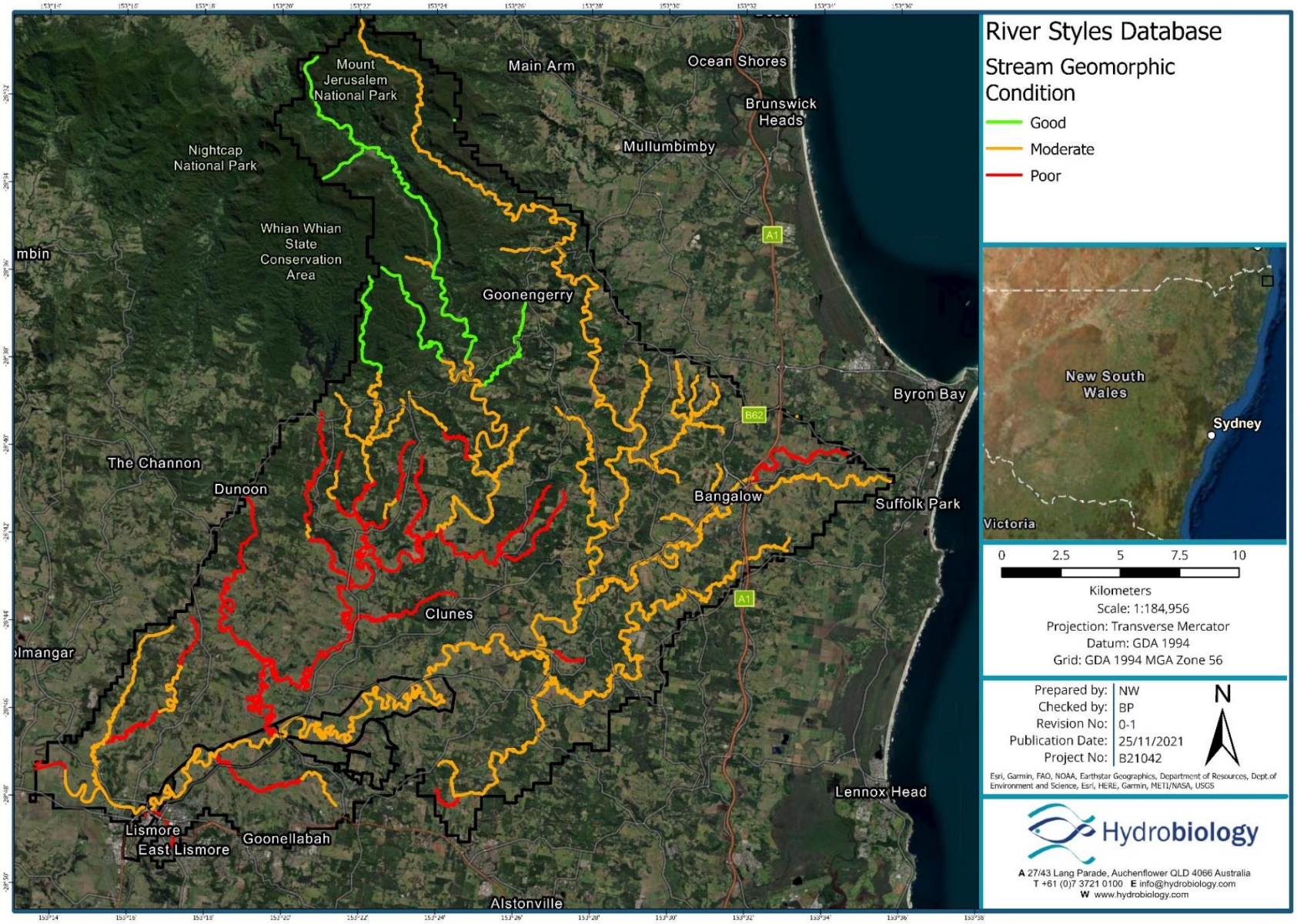


Figure 3-5 NSW River Styles Stream Condition mapping within the Wilsons River Catchment.

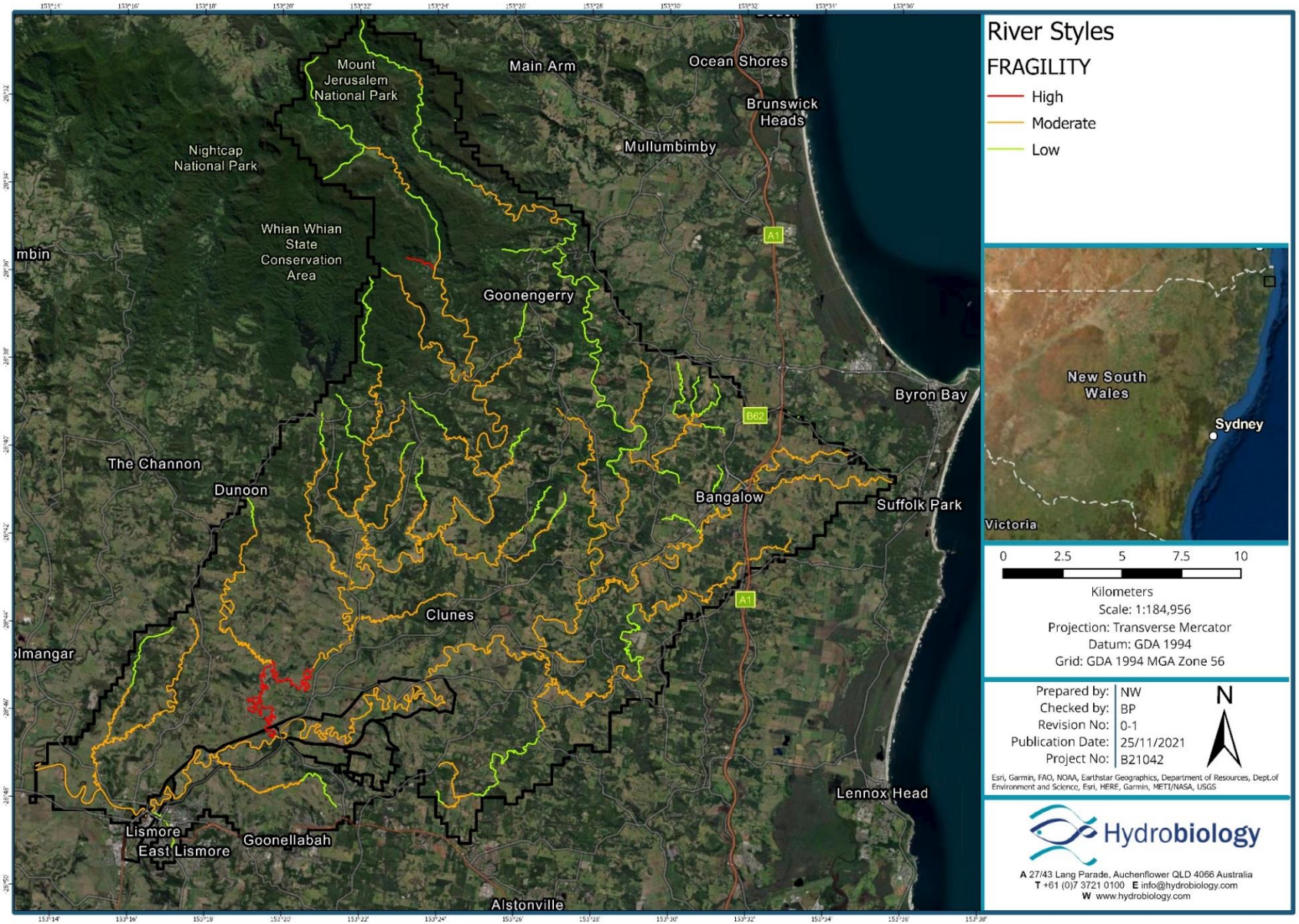


Figure 3-6 NSW River Styles Fragility mapping within the Wilson River Catchment.

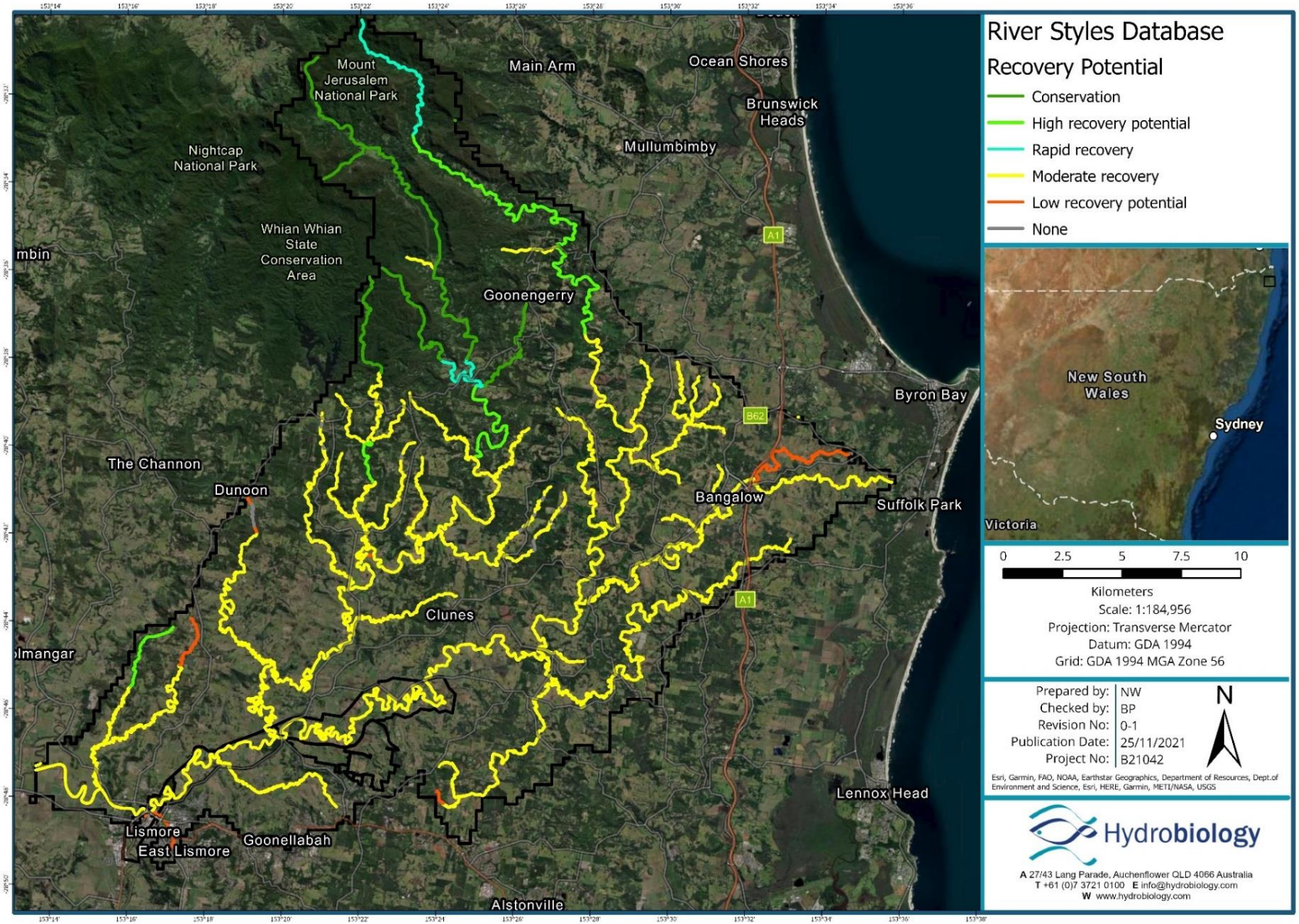


Figure 3-7 NSW River Styles Recovery Potential mapping within the Wilsons River Catchment.

3.1.4 HABITAT

Microhabitats such as (macrophytes) aquatic plants, woody debris and rocky substrate provide habitat diversity to aquatic fish, macroinvertebrates, and other animals. As with many river systems in South-East Australia there has been a long history of de-snagging (removal of structures) within the Richmond River catchment, resulting in the loss of breeding, resting and feeding sites for aquatic fauna (Dawson, 2002). Extensive land clearing in the catchment has removed important riparian habitat such as trailing and overhanging vegetation, as well as increasing erosion and subsequent sediment input into the system.

During a survey conducted in 2014 it was noted that habitat condition was poor at sites within the Wilson's River catchment (including within the study reaches) due to the smothering by fine sediments, riparian clearing and the lack of woody debris, macrophytes and riffles (Ryder *et al.*, 2015).

3.1.5 WATER QUALITY

RICHMOND RIVER

As described above, the Richmond River catchment has undergone significant historical land use changes. Other anthropogenic changes have included wetland draining through flood mitigation controls, construction of farm dams, farmland management practices, and a significant increase in population. These shifts have resulted in a deterioration in water quality in the catchment. Monitoring within the estuary showed that Water Quality Objectives (WQOs) (DECCW, 2006) developed for the Richmond River and ANZG (ANZG, 2018) guideline levels were not being achieved for the following (Cavanagh *et al.*, 2007):

- Dissolved oxygen
- pH
- Turbidity
- Nutrients (phosphorous and nitrogen)
- Chlorophyll-a
- Faecal coliforms

Pollutant loads responsible for high turbidity and nutrient levels are primarily derived from surrounding agricultural land use. The Wilsons River and upper Richmond River catchments are considered to contribute the highest sediment input into the estuary. Additionally, the Wilsons River catchment is predicted to be the primary source of phosphorous into the system, through agricultural fertilisers (Cavanagh *et al.*, 2007). Nutrient rich sediments are delivered into the system during flood events due to erosion within the catchment.

WILSONS RIVER

A study conducted in 2014 included four sampling points on the Wilsons River, including one (WR4) at Boat Harbour Nature Reserve on the border of both study reaches (Ryder *et al.*, 2015) (Figure 3-8). The results showed that turbidity, chlorophyll-a, nutrients (Total nitrogen, total phosphorous, bioavailable nitrogen and soluble reactive phosphorus) were above ANZECC (2000) maximum thresholds during most sampling events and scored a water quality grade of 'F' (Table 3-1). It was noted that the number of exceedances tended to increase downstream and with increasing catchment area.

3.1.6 FISH COMMUNITIES

There were no fish distribution data available specific to the study reaches or the Wilsons River. Data from the wider Richmond River catchment indicated that 28 native and 1 non-native fish species are present within the region (Table 3-2).

Table 3-1 Water quality monitoring results from the Wilsons River, taken from Ryder et al. (Ryder *et al.*, 2015). Numbers represent the total number and percent of exceedances.

Site	pH	DO %	Turbidity	Chl-a	TN	TP	NOx	SRP	WQ Grade
WR1	22 (31%)	6 (9%)	69 (99%)	10 (83%)	10 (83%)	10 (83%)	12 (100%)	12 (100%)	F
WR2	2 (17%)	7 (58%)	11 (92%)	10 (83%)	11 (92%)	12 (100%)	12 (100%)	12 (100%)	F
WR3	5 (42%)	4 (33%)	12 (100%)	10 (83%)	10 (83%)	11 (92%)	12 (100%)	12 (100%)	F
WR4	0	2 (33%)	4 (67%)	3 (50%)	4 (67%)	6 (100%)	6 (100%)	6 (100%)	F

3.1.7 MACROINVERTEBRATES

Although no macroinvertebrate data specific to the study reaches could be found, surveys conducted in 2014 in the Wilsons River suggested that communities were limited by a lack of riparian vegetation and low in-stream habitat diversity (e.g. woody debris, macrophytes), as well as smothering of habitat by fine sediments, likely due to erosion (Ryder *et al.*, 2015).

3.1.8 MATTERS OF NATIONAL AND STATE ENVIRONMENTAL SIGNIFICANCE (MNES & MSES)

The results of a MNES and MSES search of the study area are summarised in Table 3-3.

3.1.9 THREATENED SPECIES

The following aquatic/semi-aquatic species or species habitat may occur within the area:

- Fish:
  - *Maccullochella ikei* (Eastern freshwater Cod)
  - *Mogurnda adspersa* (Purple-spotted Gudgeon)
- Frogs:
  - *Mixophyes fleayi* (Fleay's Frog)
  - *Mixophyes iteratus* (Giant Barred Frog)
- Plants:
  - *Persicaria elatior* (Tall Knotweed)

DISTRIBUTION WITHIN THE STUDY REACHES

Interrogation of the NSW state database (Bionet) shows records of the Giant Barred Frog (*M. iteratus*) that potentially overlap the study reaches (Figure 3-9). Records of the Fleay's Frog (*M. fleayi*) tended to be restricted to the upper catchment and national parks to the north and records of Tall Knotweed (*P. elatior*) were restricted to the lower catchment and coastal region to the south-east. The closest record for Eastern freshwater Cod (*M. ikei*) was located over 230 km south in the Nambucca River catchment. There were no records for Purple-spotted Gudgeon (*M. adspersa*) in the state database.

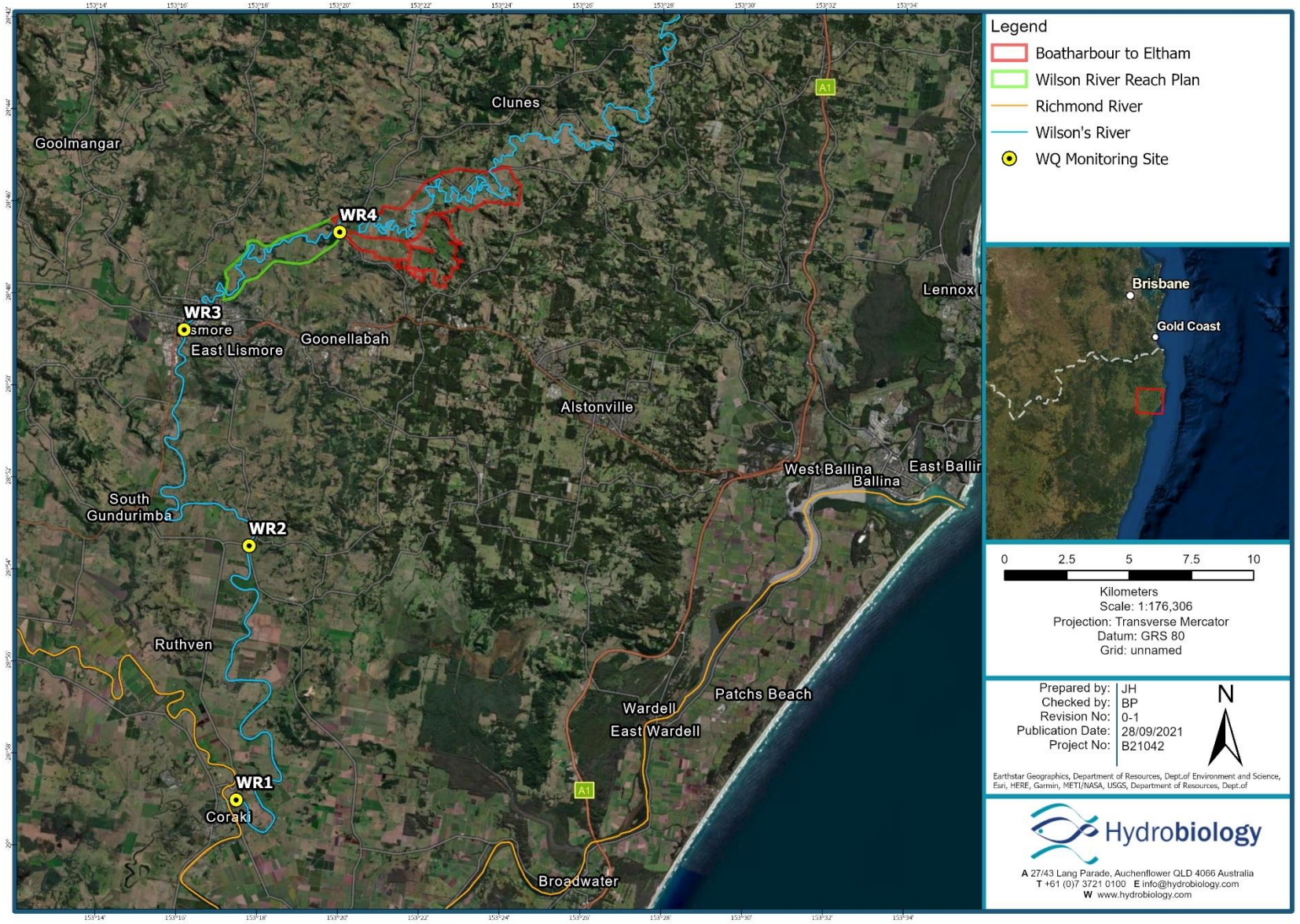


Figure 3-8 WQ monitoring sites sampled in 2014 (Ryder *et al.*, 2015).

Table 3-2 Fish species recorded from the Richmond River catchment (Harris *et al.*, 1996).

Species	Common name	Native	Non-native
Acanthopagrus australis	yellowfin bream	✓	
Ambassis agassizii	Agassiz's glassfish	✓	
Anguilla australis	southern shortfin eel	✓	
Anguilla reinhardtii	longfin eel	✓	
Arius graeffei	blue catfish	✓	
Arrhamphus sclerolepis	snubnose garfish	✓	
Carcharhinus leucas	bullshark	✓	
Gambusia holbrooki	mosquitofish		✓
Gnathanodon speciosus	golden trevally	✓	
Gobiomorphus australis	striped gudgeon	✓	
Gobiomorphus coxii	Cox gudgeon	✓	
Herklotsichthys castelnaui	Southern Herring	✓	
Hypseleotris compressa	empire gudgeon	✓	
Hypseleotris galii	firetail gudgeon	✓	
Hypseleotris spp	carp gudgeon	✓	
Liza argentea	flat-tail mullet	✓	
Macquaria colonorum	estuary perch	✓	
Macquaria novemaculeata	Australian bass	✓	
Melanotaenia duboulayi	crimsonspotted rainbowfish	✓	
Mugil cephalus	sea mullet	✓	
Notesthes robusta	bullrout	✓	
Philypnodon grandiceps	flathead gudgeon	✓	
Philypnodon sp1	flathead gudgeon	✓	
Platycephalus fuscus	dusky flathead	✓	
Potamalosa richmondia	Australian freshwater herring	✓	
Pseudomugil signifer	Pacific blue eye	✓	
Retropinna semoni	Australian smelt	✓	
Tandanus tandanus	freshwater catfish	✓	
Trachystoma petardi	pinkeye mullet	✓	

Table 3-3 MNES and MSES search of study area (with 2km buffer).

Legislation/ Directory	Protection areas/species	Details
MNES		
Environmental Protection and Biodiversity Conservation Act 1999	National heritage places	There are no national heritage properties listed under the EBPC act that are located within the site or surrounds.
	Wetlands of international significance (Ramsar wetlands)	There are no mapped wetlands of international significance within the site and surrounds.
	Commonwealth marine waters	There are no Commonwealth marine waters mapped within the site or surrounds.
	World heritage properties	No world heritage properties occur within the site or surrounds.
	Great Barrier Reef Marine Park	The GBRMP does not overlap with the site or surrounds. Wilsons River is not located within a GBR catchment.
	Listed Threatened Ecological Communities (TECs)	Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and Southeast Queensland ecological Community (endangered) Lowland Rainforest of Subtropical Australia (critically endangered)
	Listed threatened species	59 species
	Listed Migratory Species	16 species
Wet Tropics World Heritage Protection and Management Act 1993	Wet tropics world heritage area	The site and surrounds are not located within any Wet Tropics World Heritage catchments.
Directory of Important Wetlands in Australia	Wetland of national importance	There are no mapped wetlands of national importance within the site and surrounds.
MSES		
Biodiversity Conservation Act 2016	Endangered Ecological Communities	3 endangered communities
Fisheries Management Act 1994	Fish Communities and Threatened Species Distributions of NSW	Indicative habitat identified for 1 species in study reach and for 1 species in the wider catchment.

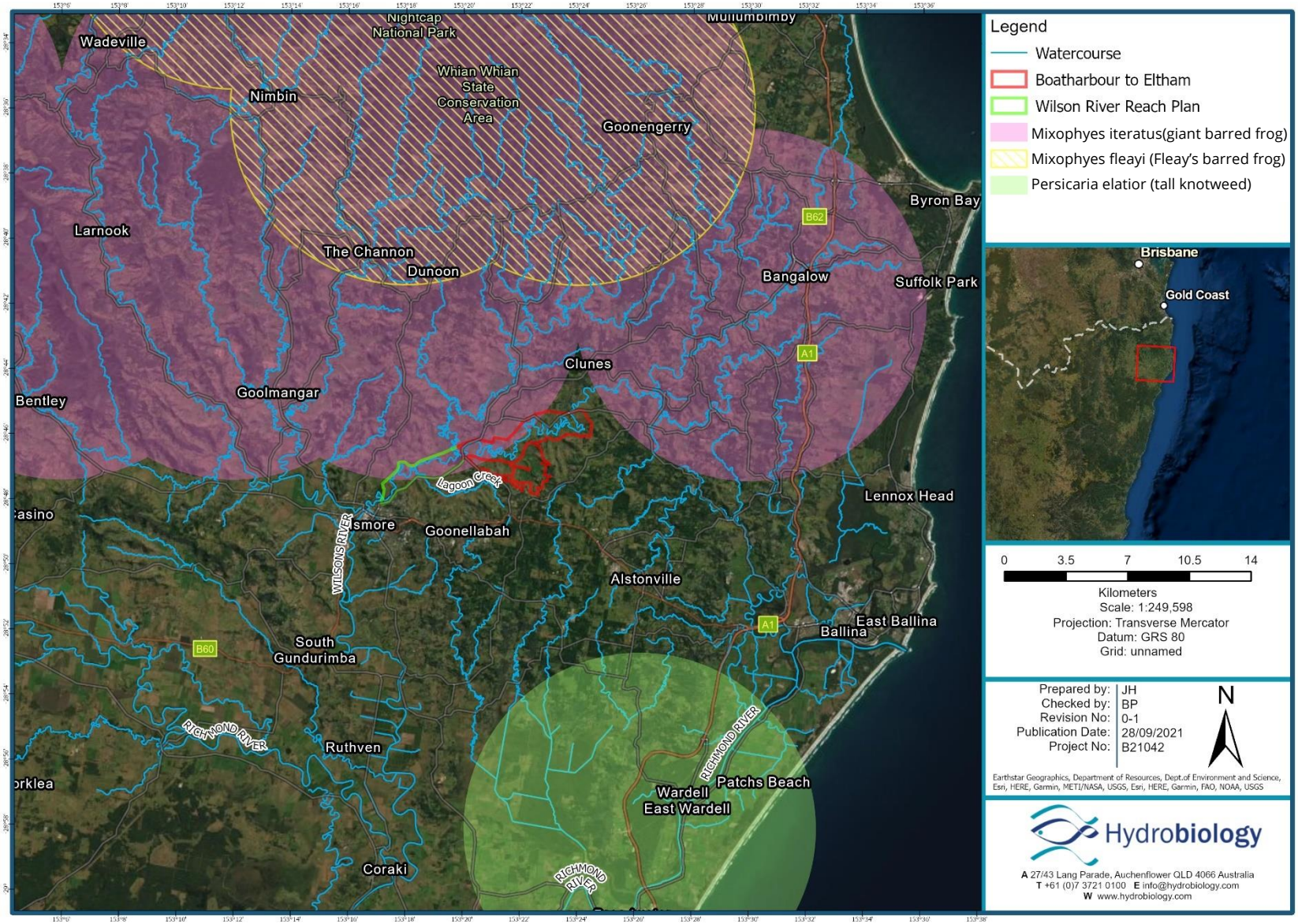


Figure 3-9 Bionet records of threatened species within the region (DPIE, 2021a). Records for threatened species are denatured to 0.1 degree (~10km)

INDICATIVE SUITABLE FISH HABITAT

Maccullochella ikei (eastern freshwater cod)

M. ikei is an internationally and nationally listed threatened species endemic to the Richmond and Clarence River systems of northern New South Wales (Butler and Rowland, 2009). Anthropogenic-induced environmental impacts occurring throughout the 20th century including, droughts, bushfires, flooding, and releases of mining waste, resulted in a significant reduction in the abundance and range of *M. ikei*. By the late 1970s, the species was considered extinct in the Richmond River system, with only small populations remained in isolated sub-catchments of the Clarence River system (Butler *et al.*, 2014).

Indicative modelling (DPI, 2016) indicated that suitable habitat includes tributaries of Wilsons River to the north of the study area (Figure 3-10).

Mogurnda adspersa (southern purple spotted gudgeon)

M. adspersa is listed as endangered in NSW. Indicative modelling (DPI, 2016) indicated that suitable habitat includes Lagoon Creek, a tributary of Wilsons River that lies within the Wilson River Reach Plan study area (Figure 3-10).

3.1.10 THREATENED SPECIES HABITAT REQUIREMENTS

The habitat requirements and associated references for the listed threatened species are summarised in Table 3-4.

3.1.11 SPECIES RECOVERY PLANS

National/state species Recovery Plans were available for:

- *M. ikei* (DPI, 2021)
- *M. fleayi* (Hines, 2002)
- *M. iteratus* (Hines, 2002)

The relevant potential threats and recovery actions of these species are summarised in Table 3-5. Where Recovery Plans were unavailable, information for *M. adspersa* has been summarised from the Primefact species profile (DPI, 2017), and information for *P. elatior* has been summarised from Approved Conservation Advice (DEWHA, 2008).

3.1.12 LISTED THREATENED ECOLOGICAL COMMUNITIES (TECS)

The following TECs may occur within the area:

- Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and Southeast Queensland ecological Community (endangered)

The following TEC is likely to occur within the area:

- Lowland Rainforest of Subtropical Australia (critically endangered).

3.1.13 ENDANGERED ECOLOGICAL COMMUNITIES AND FAUNA KEY HABITATS

The Endangered Ecological Communities (EECs) and fauna key habitats reported or considered likely to occur in the study reach are displayed in Table 3-6 and Figure 3-11 (DPIE, 2010; McKinley and Murray, 2019). One fauna key habitat was identified, located within Boat Harbour Nature Reserve which overlaps both study reaches. The nature reserve falls within the Lowland Rainforest of Floodplain EEC. This EEC and to a lesser extent the EEC Sub-tropical Coastal Floodplain Forest occur along the riparian zones of both study reaches.

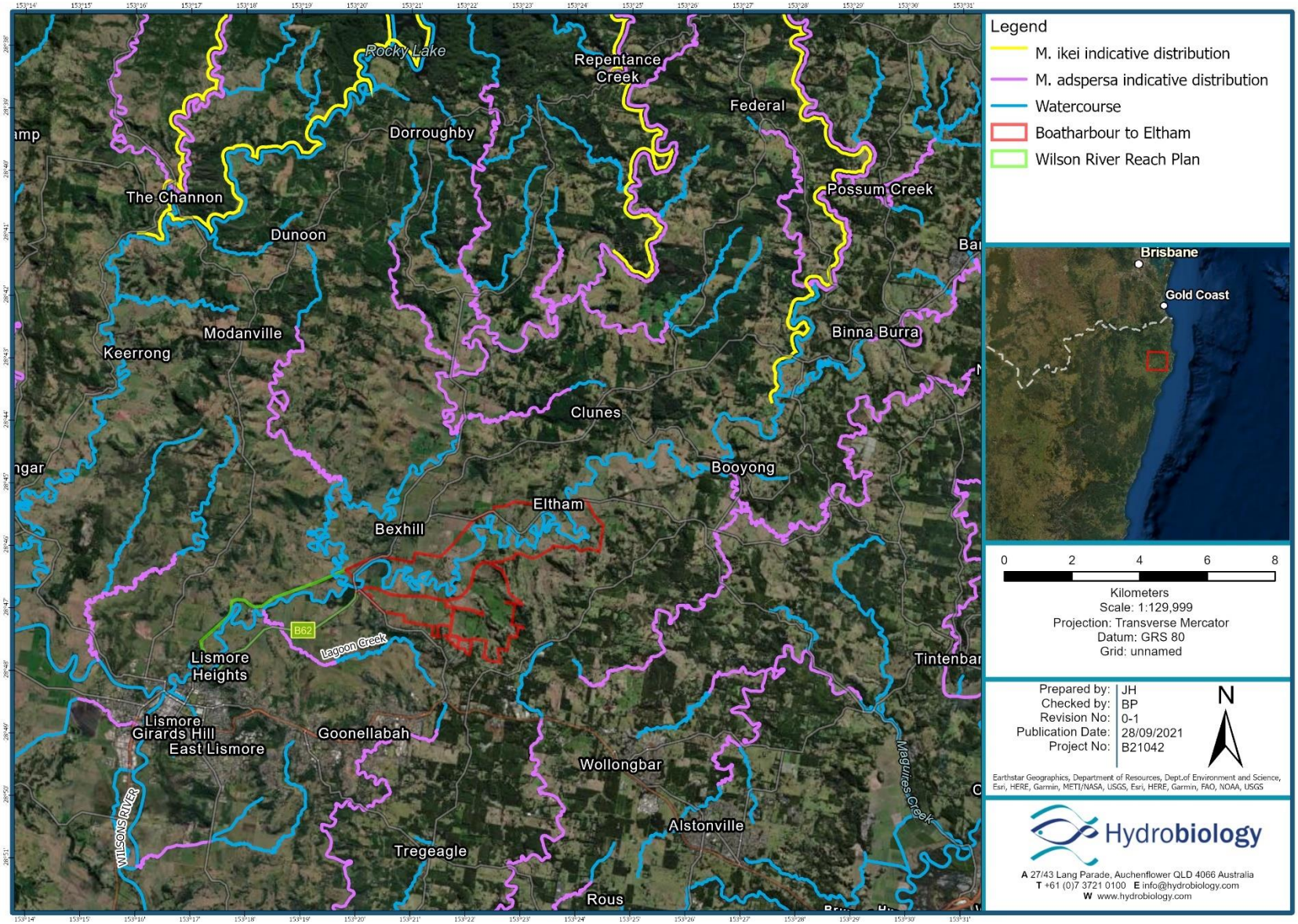


Figure 3-10 Indicative distributions of threatened species associated with the study reaches (DPI, 2016).

Note: M. ikei – eastern freshwater cod; M. adspersa - southern purple-spotted gudgeon

Table 3-4 Threatened species details.

Species	Common name	Photograph	Description	Foraging/sheltering habitat	Spawning habitat	References
Fish						
Maccullochella ikei	Eastern freshwater Cod		A large olive to yellowish-green or golden cod, with a concave forehead profile, pelvic-fin rays with elongate filaments, distinct reticulated mottling on the head and body; belly whitish.	Pristine sections of clear, flowing, freshwater rocky streams with plenty of logs, woody debris, and other in-stream cover.	Slow-flowing pools and bedrock shelves. Hard substrates (cobbles boulders and bedrock), undercut root masses of *Potamophila parviflora*.	(Bray and Gomon, 2021), (Butler and Rowland, 2009; Butler *et al.*, 2014). Photograph: (DPI, 2021)
Mogurnda adspersa	Southern purple spotted gudgeon		A dark brownish to yellowish-brown gudgeon becoming paler below, with a row of dark blotches surrounded by red and white spots on the sides, and sometimes iridescent blue markings.	Freshwater rivers, creeks, and billabongs. They prefer still or slow-flowing waters, and usually shelter among aquatic vegetation, overhanging bank vegetation, rocks, snags, and other woody debris.	Rocks, logs, or broad-leafed aquatic vegetation	(Pusey *et al.*, 2004; DPI, 2017). Photograph: (DPI, 2017)
Amphibians						
Mixophyes fleayi	Fleay's barred frog		Medium to large frogs growing up to 90 millimetres long with pale brown backs with darker blotches starting between the eyes and running down the back. The arms and legs have dark bars which widen under the legs to form a triangular pattern.	Mostly above an altitude of 600m in montane rainforest/wet sclerophyll forest streams. Shelters under leaf litter and debris and often aggregate in stony riffles.	Egg deposition occurs in the shallow riffles of streams.	(Stratford *et al.*, 2010). Photograph: (DES, 2021a)

Species	Common name	Photograph	Description	Foraging/sheltering habitat	Spawning habitat	References
Mixophyes iteratus	Giant barred frog		A very large frog (up to 115 mm) with a pointed snout and well-developed hind legs. The dorsal surface is dark brown to olive, with darker blotches and an irregular dark vertebral band commencing between the eyes and continuing posteriorly. A dark stripe runs from the snout, through the eye, terminating at a point above the forelimb. There are irregular dark spots or mottling on the flanks.	Shallow rocky streams in rainforest, wet sclerophyll forest and farmland of altitude between 100 and 1000m, or deep, slow moving streams with steep banks in lowland areas. Found amongst leaf litter within closed-canopy riparian zone.	Eggs are deposited out of the water, under overhanging banks or on steep banks of large pools	(Lemckert and Brassil, 2000; DAWE, 2021). Photograph: (DES, 2021b)
Plants						
Persicaria eliator	Tall knotweed		Tall Knotweed is an erect herb to 90 cm tall, with stalked, glandular hairs (i.e., they are knobbed when seen under a lens) on most plant parts. Its leaves are up to 11 cm long and 30 mm wide. A sheath encircles the stem at the base of each leaf, which is characteristic of its plant family. Its tiny flowers are in long, narrow spikes to 5 cm long. The pink flower-segments are less than 4 mm long.	Normally grows in damp places, especially beside streams and lakes. Occasionally in swamp forest or associated with disturbance.	-	(DPIE, 2021b)

Table 3-5 Summary of impacting processes and recovery actions from available Recovery Plans.

Potential major impacting processes	Species					Recovery Actions
	M. ikei	*M. adspersa*	*M. iteratus*	*M. fleayi*	*P. elatior*	
Loss of microhabitat (large woody debris, rocks, undercut banks, macrophytes)	✓	✓				Investigate the feasibility of re-snagging operations or the suitability of creating habitats using artificial materials.
Loss of macrohabitat (deep pools, riffles, runs, wetlands)	✓	✓	✓	✓	✓	Restore natural seasonal flow patterns and maintain connectivity and inundation of key habitat.
Loss of riparian vegetation	✓	✓	✓	✓	✓	Encourage land managers to adopt 'best practices' in the protection and regeneration of riparian vegetation.
Increased erosion and sedimentation	✓	✓	✓	✓	✓	Use effective erosion and sediment control measures. Implementation of 'best practice' soil conservation practices in the catchment.
Change in river flows (water consumption, barriers)	✓	✓	✓	✓	✓	Encourage the adoption of NSW Fisheries Policy and Guidelines for Bridges, Roads, causeways, Culverts, and Similar Structures.
Water pollution	✓	✓	✓	✓	✓	Ensure that the risk of pollution impacts is minimised.

Table 3-6 EECs considered likely to occur in the study reaches.

Full name	Short name
Lowland Rainforest on Floodplain in the New South Wales North Coast Bioregion	Lowland Rainforest on Floodplain
Sub-tropical Coastal Floodplain Forest of the NSW North Coast bioregion	Sub-tropical Coastal Floodplain Forest
Swamp sclerophyll forest on coastal floodplains of the NSW North Coast, Sydney Basin, and Southeast Corner bioregions	Swamp sclerophyll forest on coastal floodplains

3.1.14 BOATHARBOUR NATURE RESERVE

Boat Harbour Nature Reserve is known to contain remnant 'Big Scrub' communities. The Big Scrub was once the largest continuous tract of sub-tropical rainforest in Australia and is estimated to have exceeded 75 000 hectares. Of the original 75 000 hectares only about 100 hectares or 0. 13% remains as small, isolated remnants. Big Scrub remnants are important habitats for many threatened plants and animals and provide foci for the dispersal of rainforest seeds to nearby regrowth areas (NPWS, 1997).

3.2 FIELD PROGRAM

3.2.1 BACKGROUND

Several different metrics both from an ecological and geomorphic perspective were analysed in the site-based assessment for each of the sub-reaches of the reach breakdown (Figure 3-12). Overall, habitat diversity ranged from Low to High, with Low scores concentrated in Sub-reach 4, 9, 11, 13 and 17 (Figure 3-13). This aligned somewhat with the bioassessment score, with scores ranging from Fair to Good, with Fair scores concentrated in Sub-reach 4, 7, 9, 14, 15, 16, 17 (Figure 3-14). Both of these scores closely aligned with Lomandra extent (Figure 3-15), Woody Debris scores (Figure 3-16), % cover of weeds, and riparian clearing, with Low Lomandra and Woody Debris extent and greater weed presence (Figure 3-17) and riparian clearing (Figure 3-18) in the central to lower sub-reaches.

In terms of geomorphology, River Styles Geomorphic Condition rank ranged from Good-Moderate to Low (Figure 3-19). This closely aligned with habitat condition and ecological metrics above. Erosion severity ranking (Figure 3-21) and key geomorphic issues (Figure 3-20) are highlighted, with issues concentrated in Sub-reach 1, 4, 5-9 and 13-17 Results from the site based assessment are described and analysed in further detail in the following sections, with key issues summarized for management.

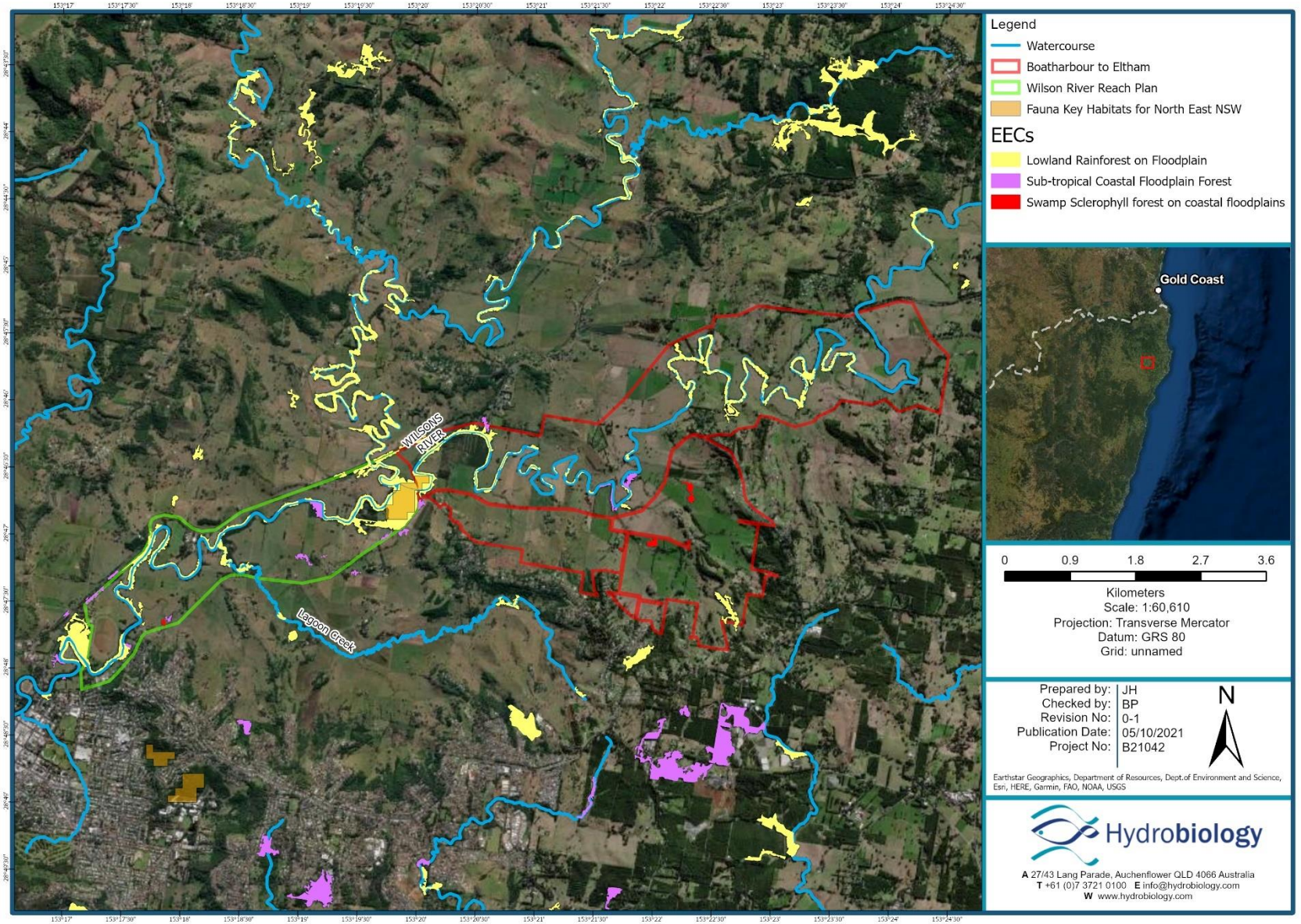


Figure 3-11 Fauna Key Habitats for North East NSW and EECs in the study area (DPIE, 2010; McKinley and Murray, 2019).

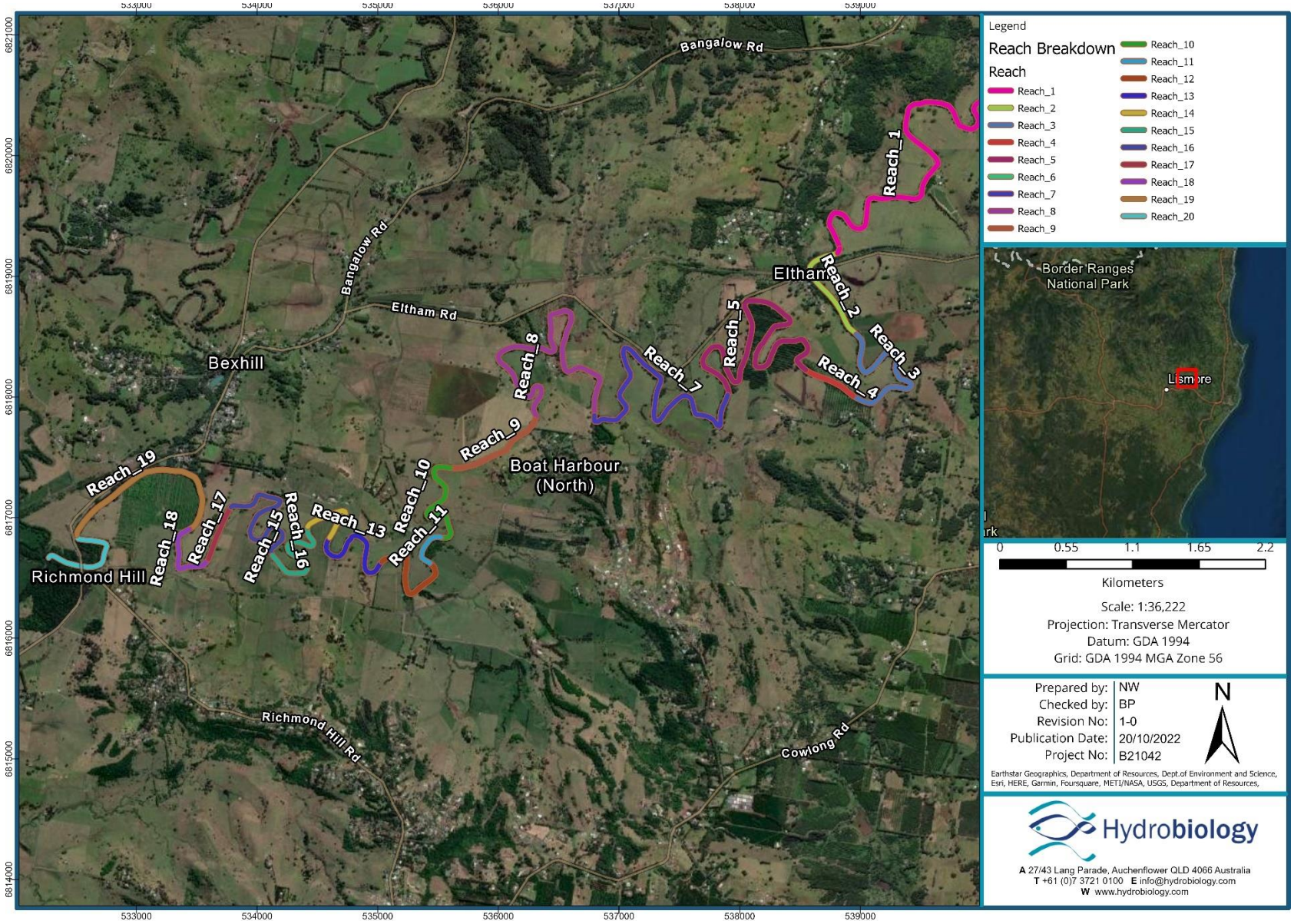


Figure 3-12 Sub-reach breakdown of the study reach, Wilsons River.

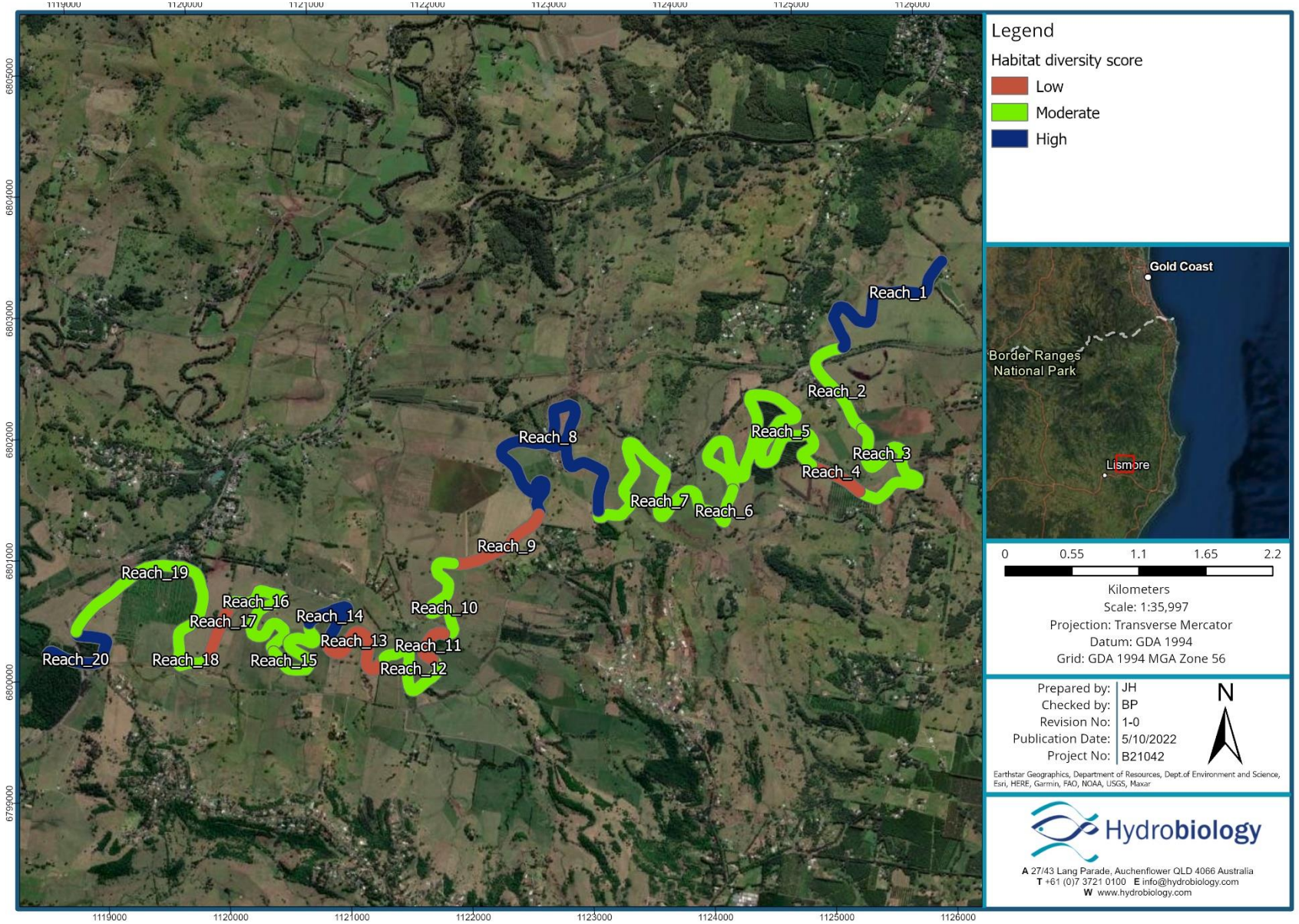


Figure 3-13 Habitat diversity scores for each sub-reach along the Wilson's River study reach.

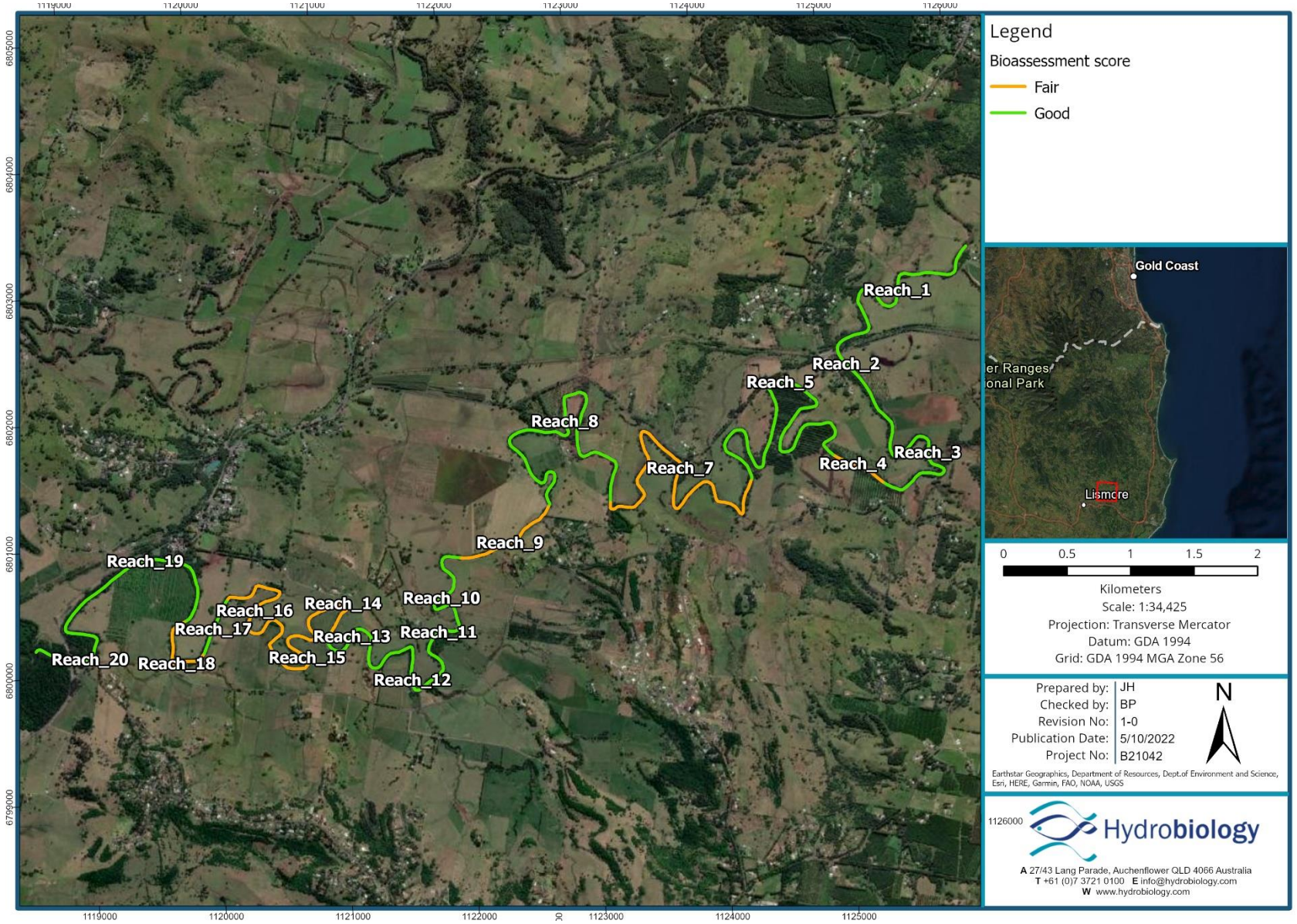


Figure 3-14 AUS Rivas Bioassessment scores for each sub-reach within the Wilson's River study reach.

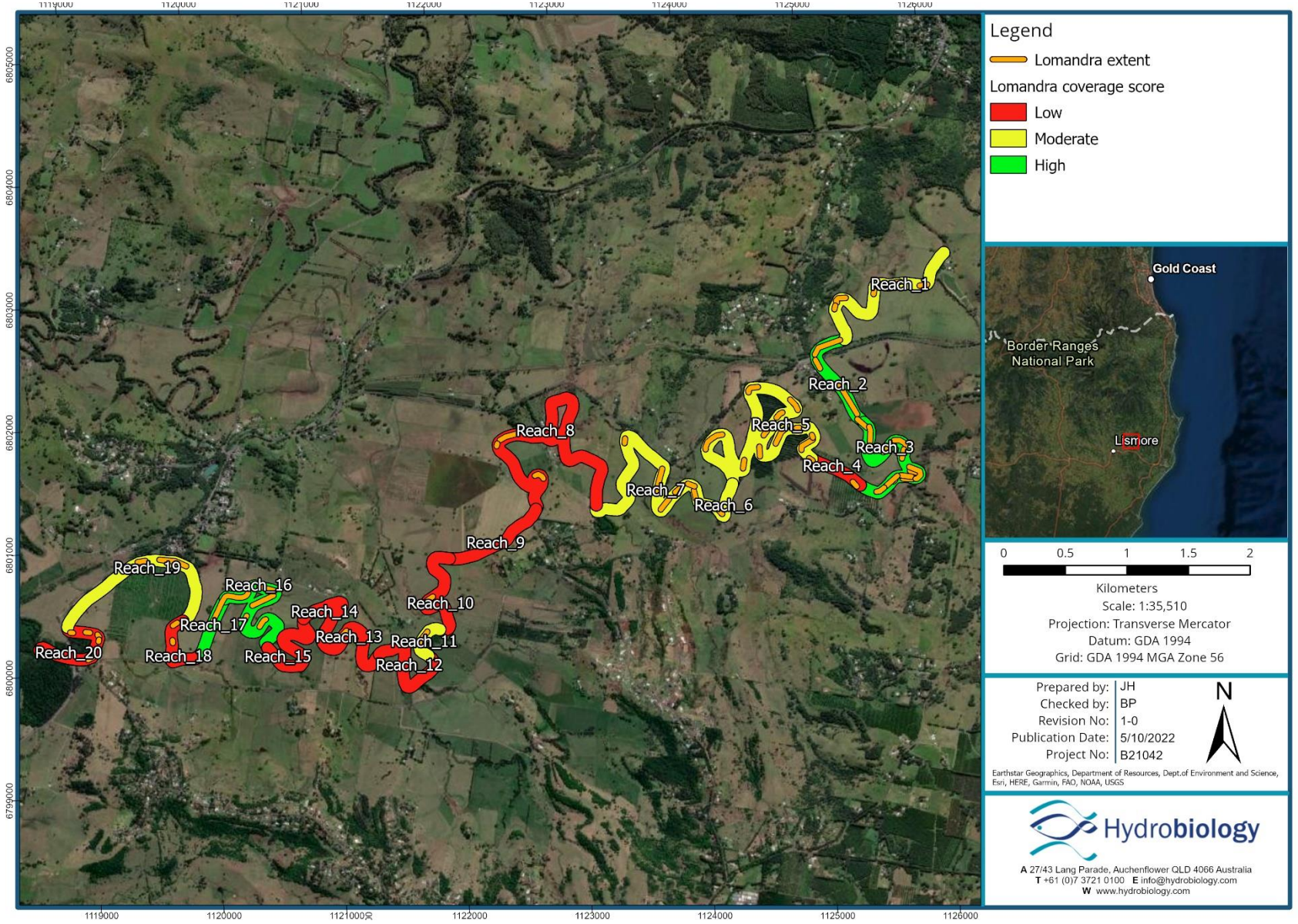


Figure 3-15 Lomandra extent and coverage scores for each sub-reach within the Wilson's River study reach.

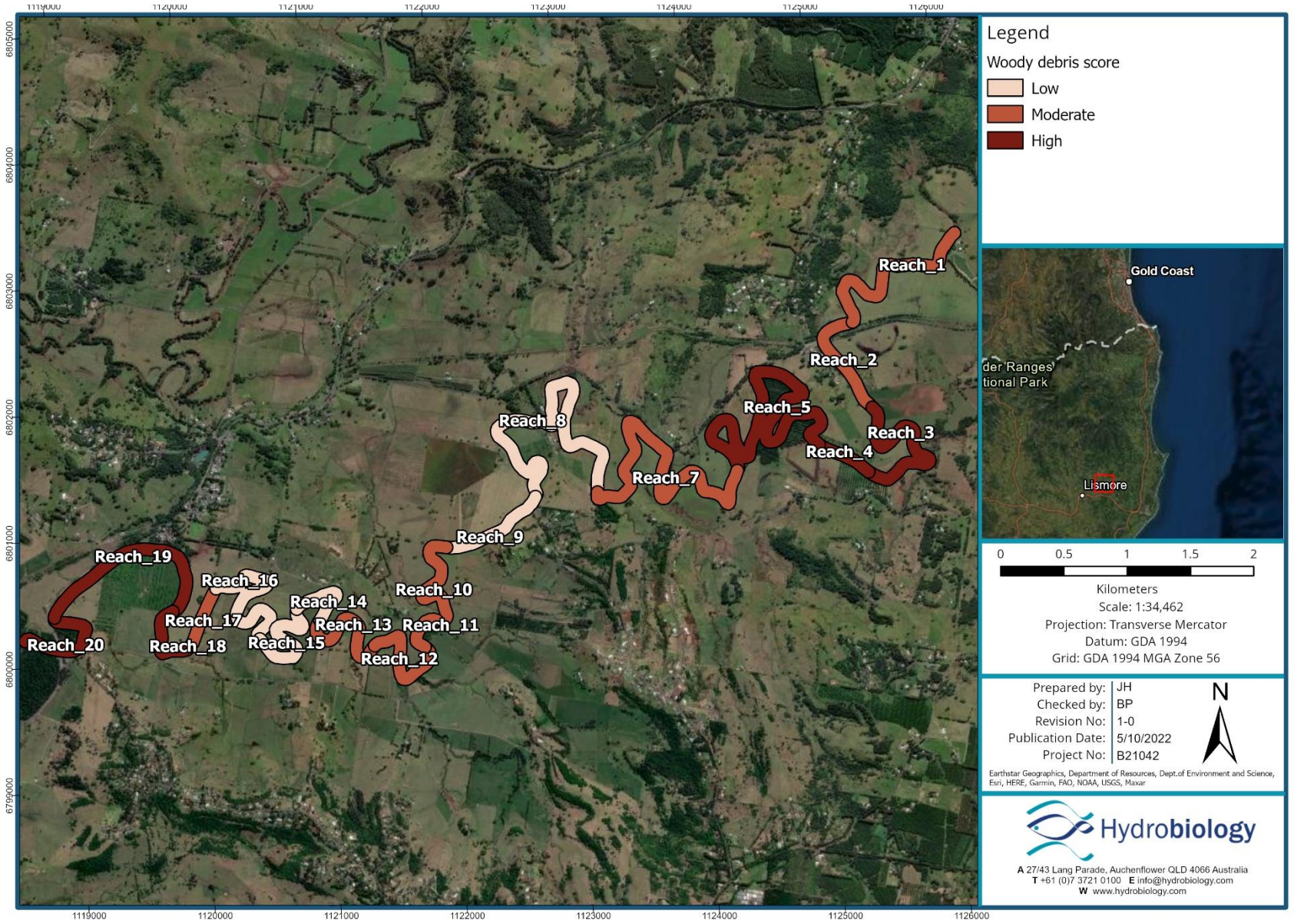


Figure 3-16 Woody debris score for each sub-reach within the Wilson's River study reach.

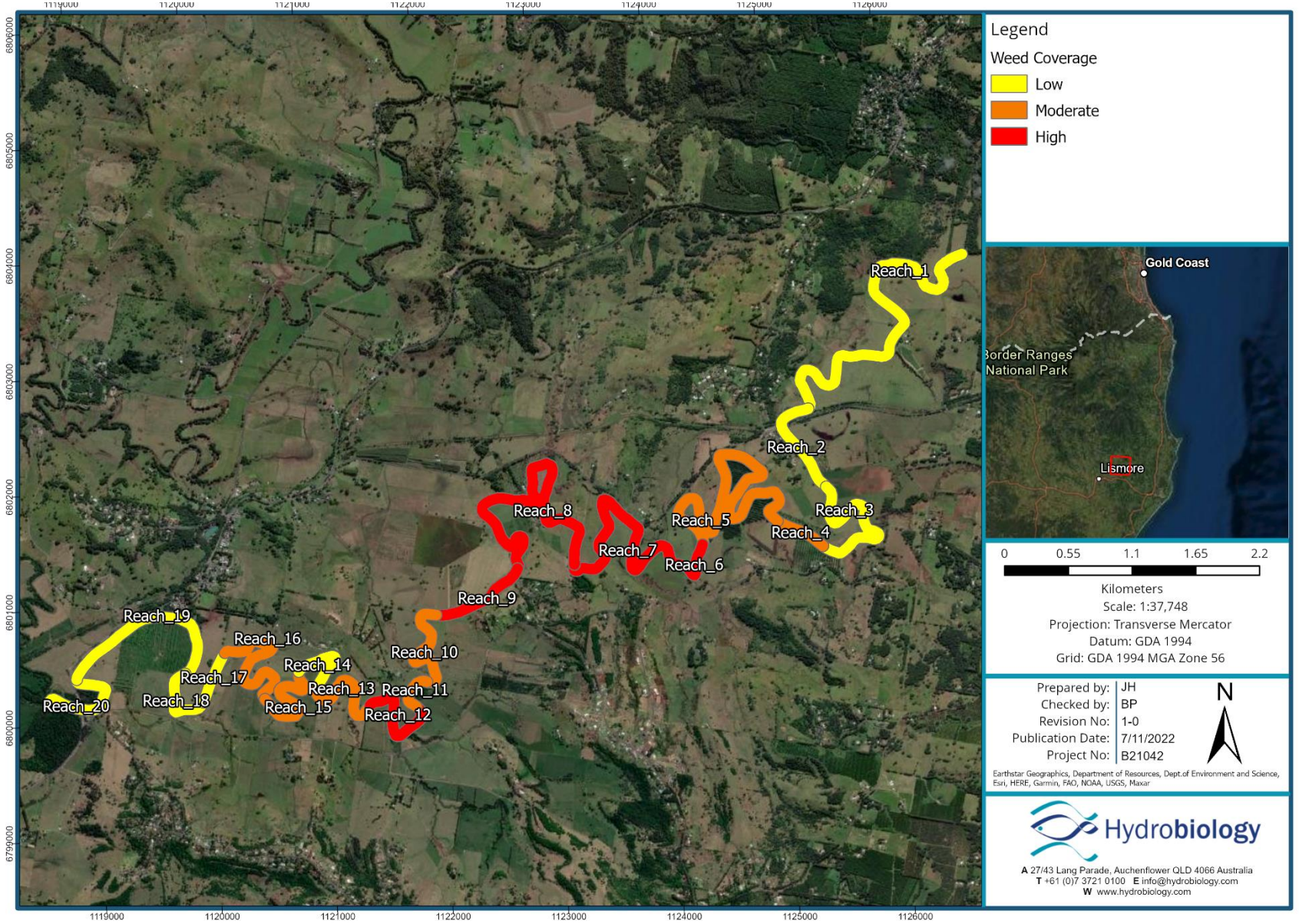


Figure 3-17 Percent weed coverage for each sub-reach within the Wilson's River study reach.

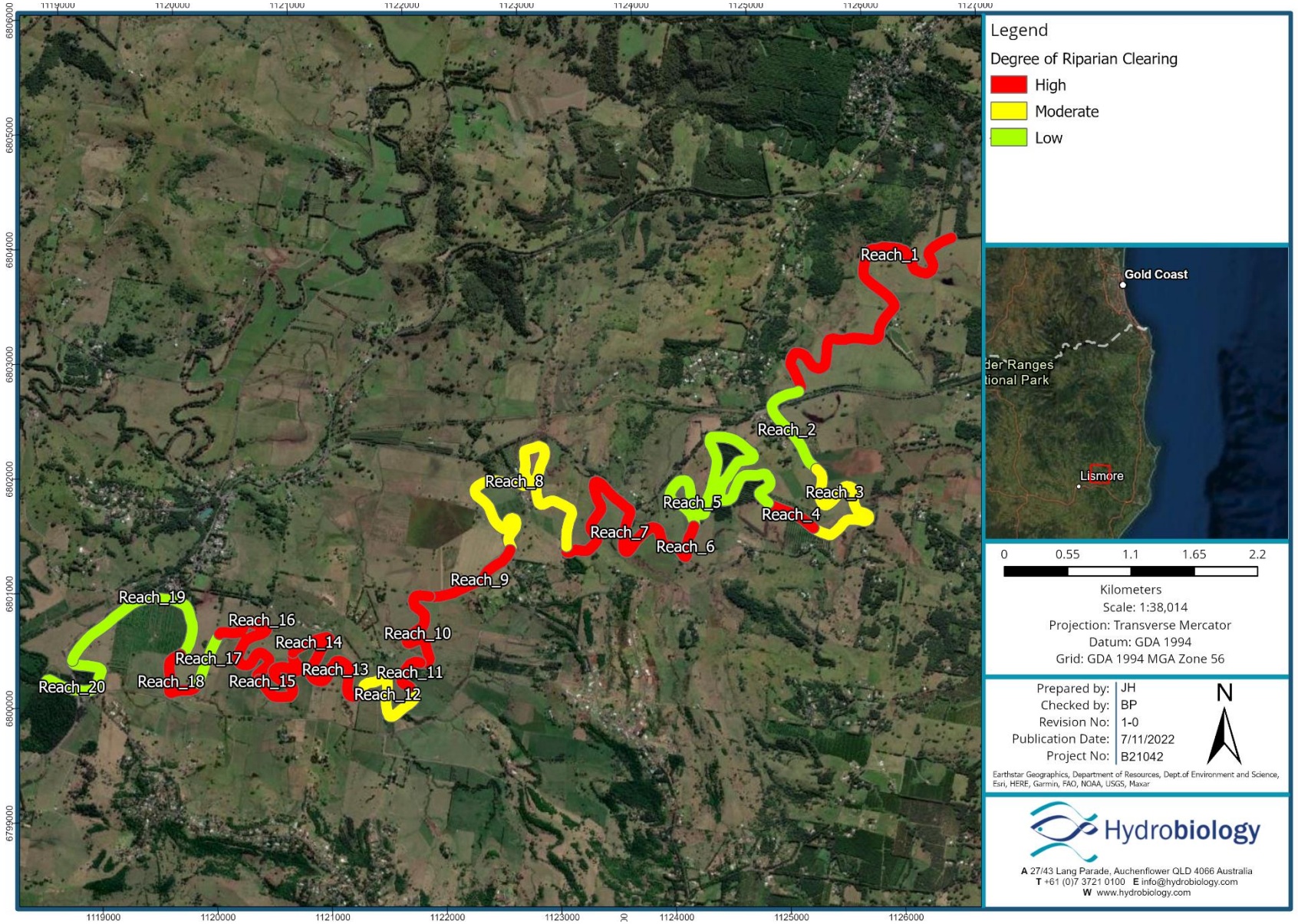


Figure 3-18 Riparian clearing scores for each sub-reach within the Wilson's River study reach.

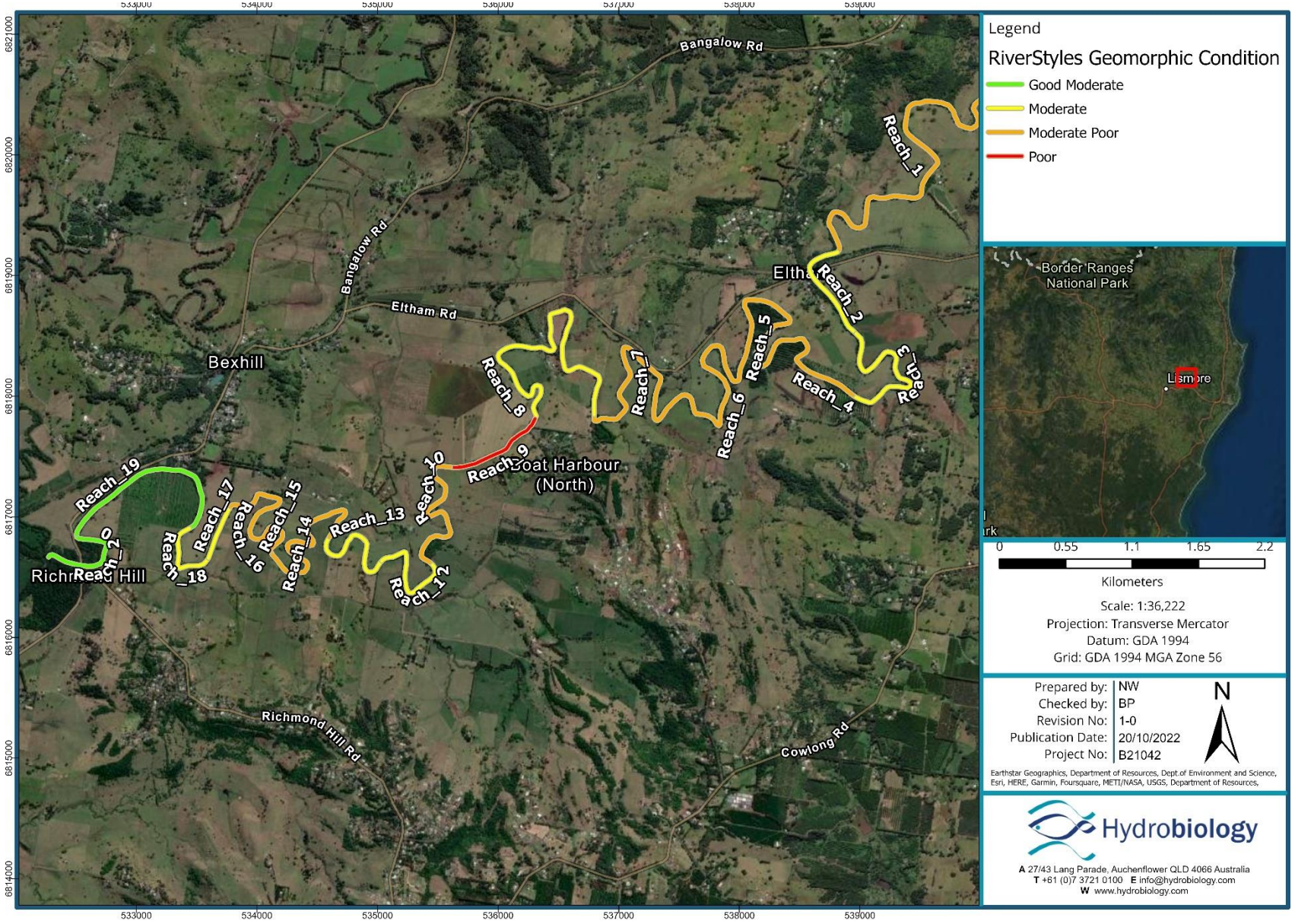


Figure 3-19 River Styles Geomorphic Condition Ranking for each sub-reach within the Wilson's study reach.

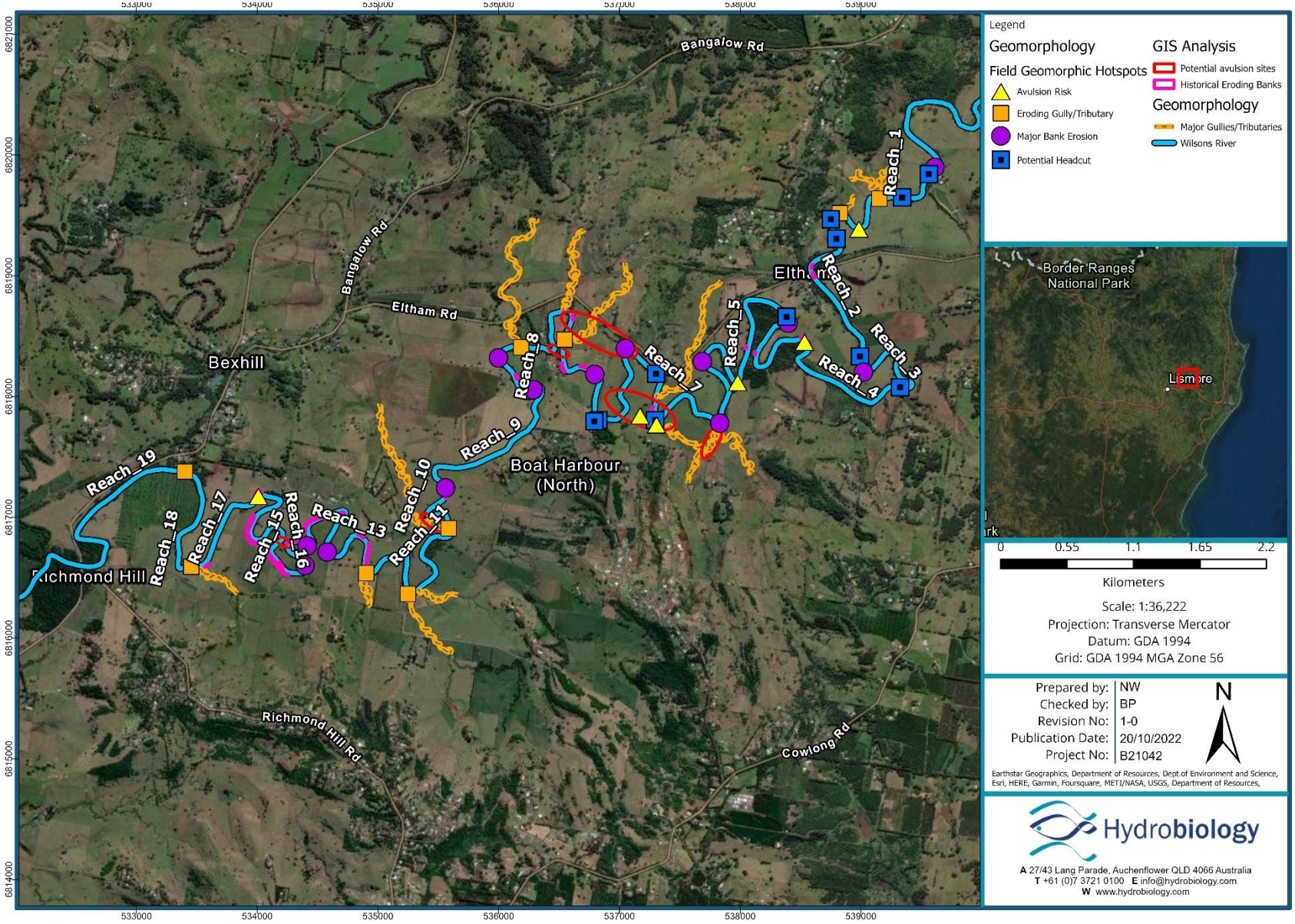


Figure 3-20 Geomorphic hotspots for the Wilson's study reach.

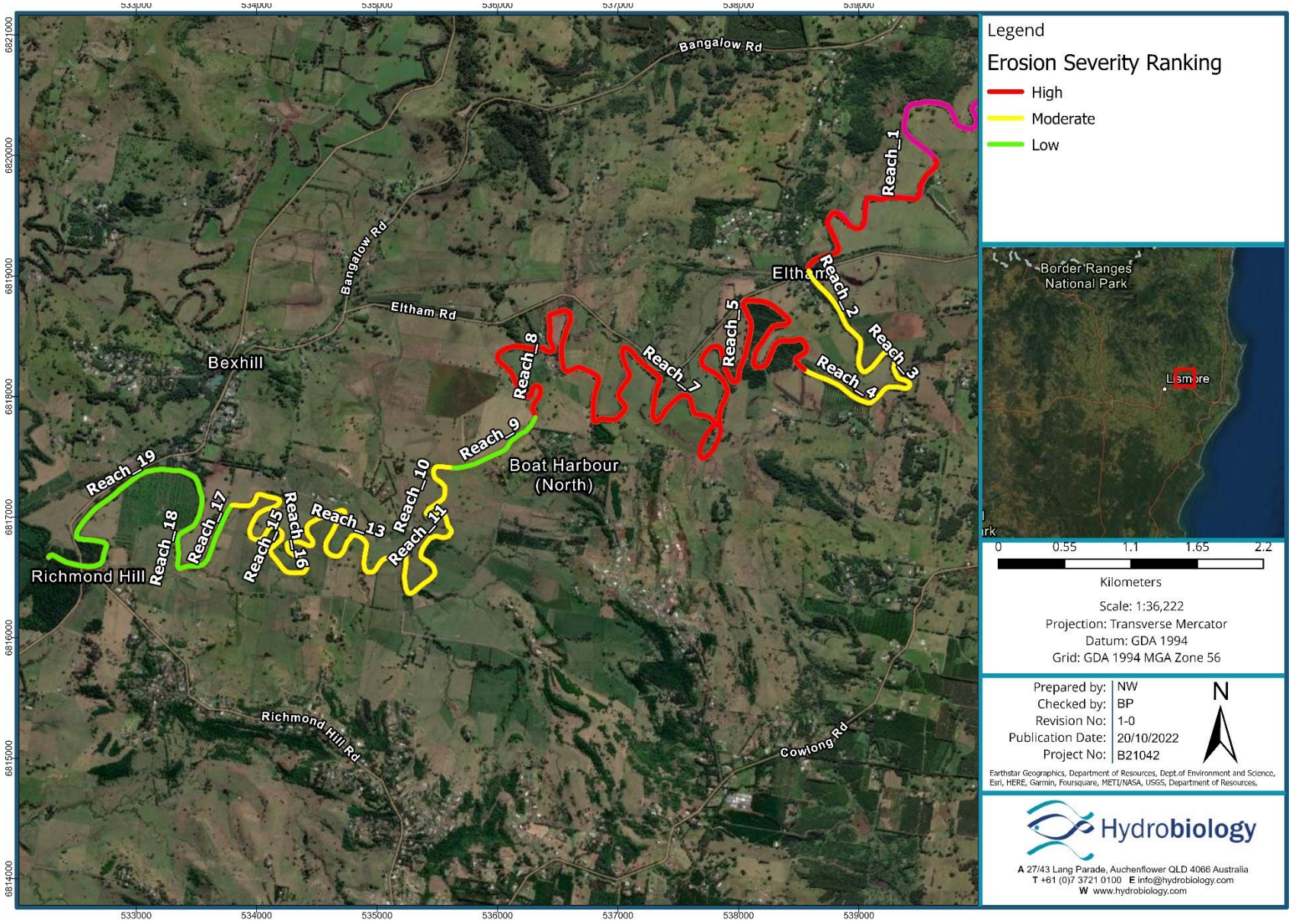


Figure 3-21 Erosion severity ranking for the Wilson's study reach.

3.2.2 WATER QUALITY

3.2.2.1 TEMPERATURE

Temperature was within the range expected for the catchment and time of year, with slight variations depending on the time of day (Figure 3-22). It should be noted that Sub-reach 14 to Sub-reach 17 were lower in temperature because they were sampled in winter (June), whereas the rest of the sub-reaches were sampled in Spring (September).

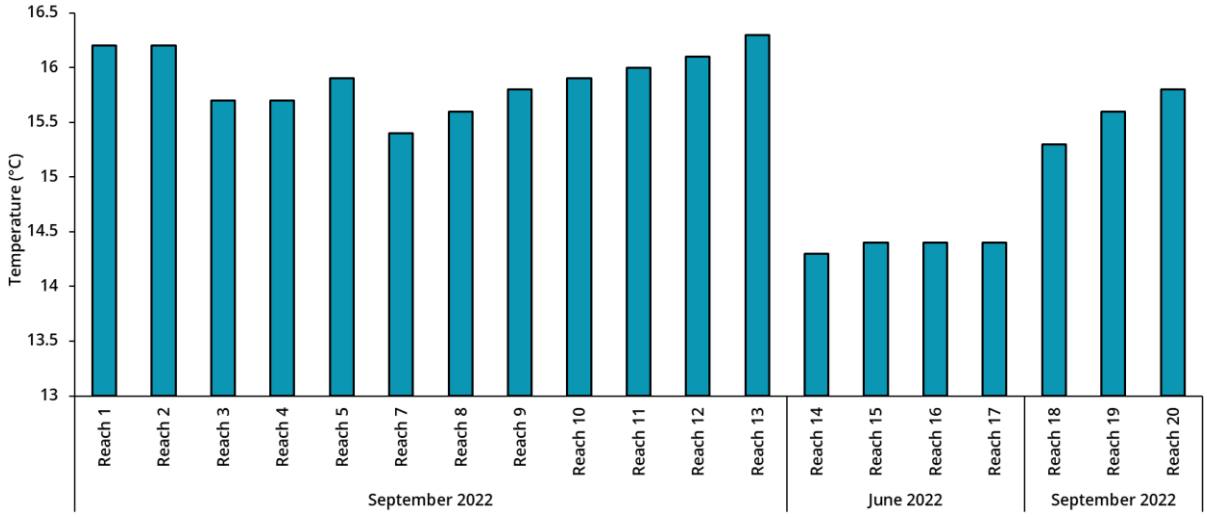


Figure 3-22 Temperature recorded at each sub-reach.

3.2.2.2 CONDUCTIVITY

Conductivity generally remained consistent between each sub-reach and was within levels expected of similar catchments (Figure 3-23). Values were slightly lower in September than in June, likely due to a rain event occurring in the days before the monitoring period.

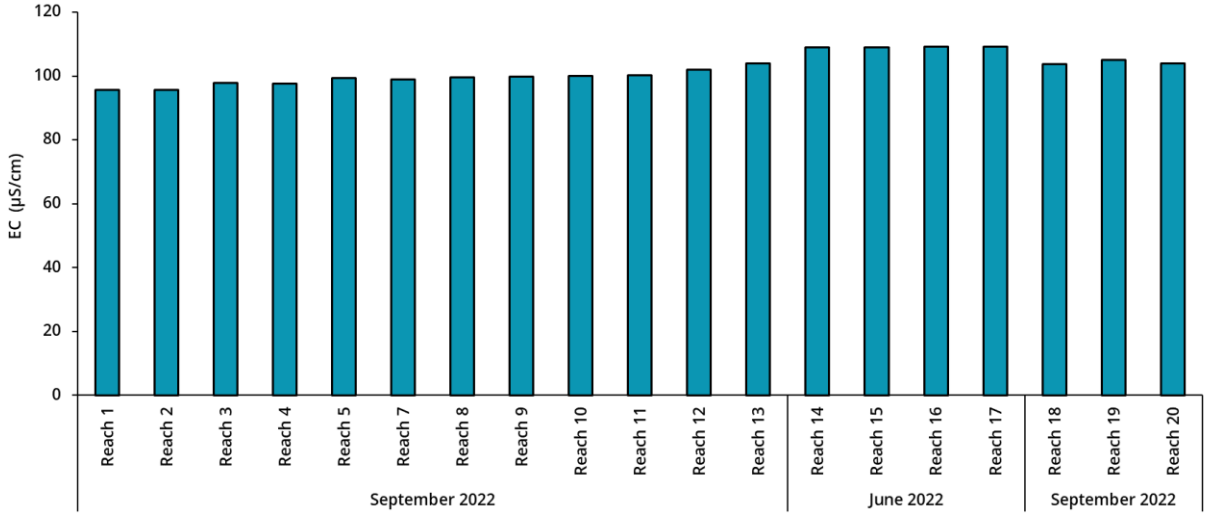


Figure 3-23 Conductivity recorded at each site.

3.2.2.3 PH

pH was circumneutral and within WQO guideline values for all sub-reaches, showing no obvious differences between seasons (Figure 3-24).

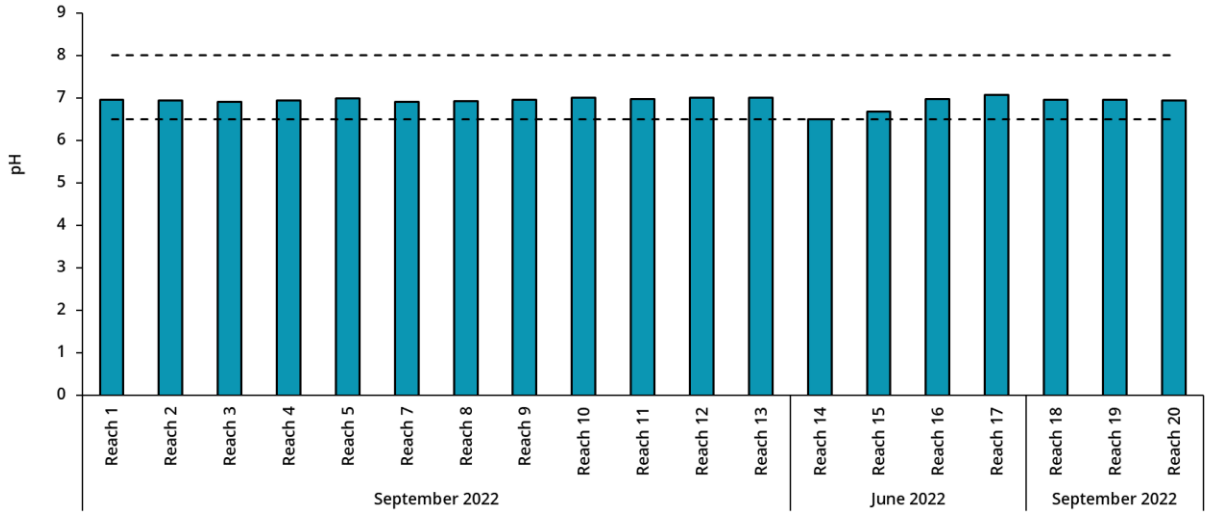


Figure 3-24 pH recorded at each site. Dotted lines represent WQO guideline values (DECCW, 2006).

3.2.2.4 DISSOLVED OXYGEN

Dissolved oxygen did not vary by sub-reach or season and was within WQOs for all sub-reaches (Figure 3-25).

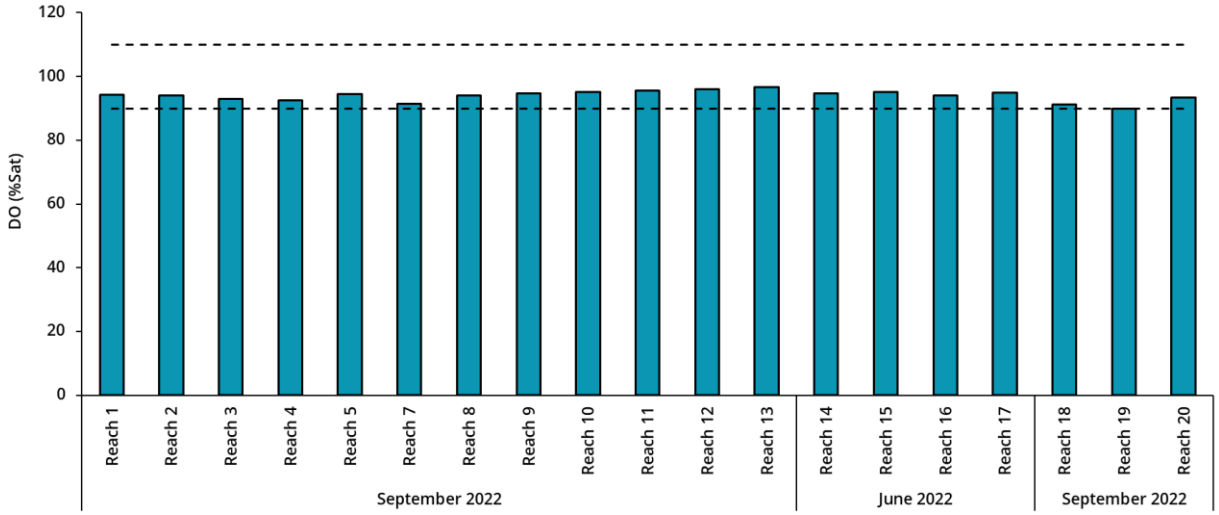


Figure 3-25 Dissolved oxygen recorded at each site. Dotted lines represent WQO guideline values (DECCW, 2006).

3.2.2.5 TURBIDITY

Turbidity did not vary by sub-reach or season and was within WQOs for all sub-reaches (Figure 3-26).

3.2.2.6 HISTORICAL COMPARISON

Water quality values recorded in the current survey were broadly similar to those recorded at Boat Harbour Nature Reserve in Autumn and Spring in 2013 (Ryder *et al.*, 2015) (Table 3-7).

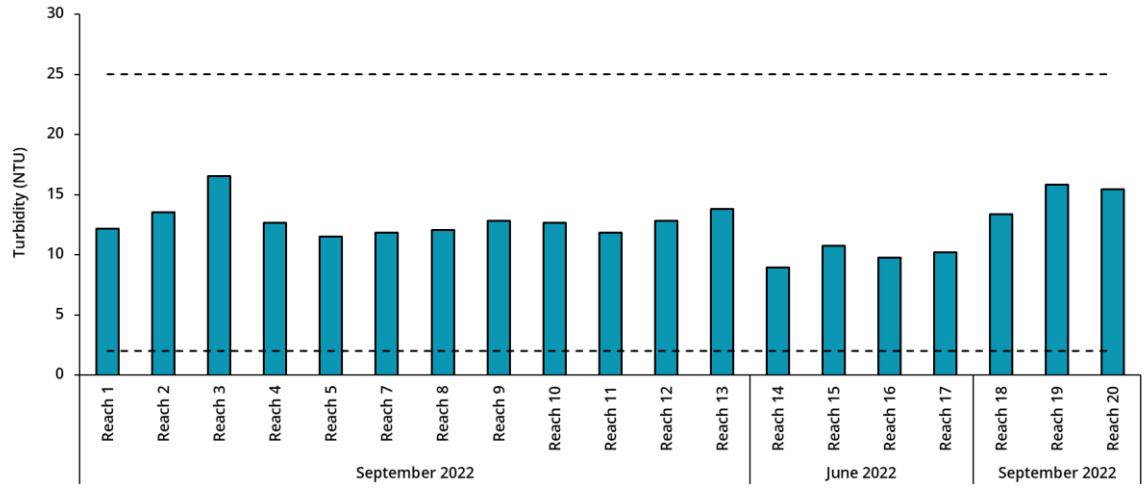


Figure 3-26 Turbidity recorded at each site. Dotted lines represent WQO guideline values (DECCW, 2006).

Table 3-7 Mean values recorded in the Wilsons River at Boat Harbour Nature Reserve. Site WR4 in Ryder et al (2015).

Site	pH	EC (µS/cm)	DO (%Sat)	Turbidity (NTU)
Wilsons River at Boat Harbour Reserve	7.85	139	84.7	11.9

3.2.3 SITE BASED ASSESSMENT OF GEOMORPHOLOGY AND ECOLOGY

3.2.3.1 GENERAL

While there were several locations in the reach where bed sedimentation was occurring, the Wilsons River study reach can be generally described as a sediment transfer zone. Its incised, deep channel would easily convey much of the sediment delivered to it from upstream/gullies/tributaries and that supplied by bank/bed erosion processes within the reach itself. Turbidity was generally low and consistent except at the gully confluences identified above.

3.2.3.2 GULLIES AND TRIBUTARIES

Figure 3-27 shows the 18 gullies identified as draining into the study reach. Photographs of the confluence of these gullies with Wilsons River are provided in Appendix C. Gullies identified as being High Risk were identified in the following sub-reaches:

- A very large gully network (Gully 5) draining into Sub-Reach 6/7. This gully drains a number of properties that have identified interest in this project. This was identified in the site visit as being potentially a major source of sediment and turbid runoff.
- Gullies 8 and 9 in Sub-Reach 8. These drain large catchment areas but do not flow through interested properties. Both were headward eroding and had considerable deposits of sediment in and around the confluence. Turbidity was also high.
- Gully 12 in Sub-Reach 10 was headward eroding and had noticeable sediment deposition at its confluence with Wilsons River. Turbidity was also higher than the Wilsons River.
- Gullies 13 and 14 in Sub-Reach 12 both drain large catchments that sit within several interested properties. The confluences are perched and comprise turbid water and depositional features.
- Gully 15 (Sub-Reach 13) drains a large catchment that sits within several interested properties. Its confluence is perched. Turbidity reflected that seen in Wilsons River.

In addition to the above a number of Moderate Risk tributaries were mapped, including Gully 1 (Sub-Reach 1), Gullies 3 and 4 (Sub-Reach 3), Gullies 6 and 7 (Sub-Reach 6/7), Gully 10 (Sub-Reach 8), Gully 11a (Sub-Reach 11), and Gully 17 and 18 (Sub-Reach 19). These gullies (Major/Moderate Risk) are addressed further as geomorphic issues in the sub-reach breakdowns.

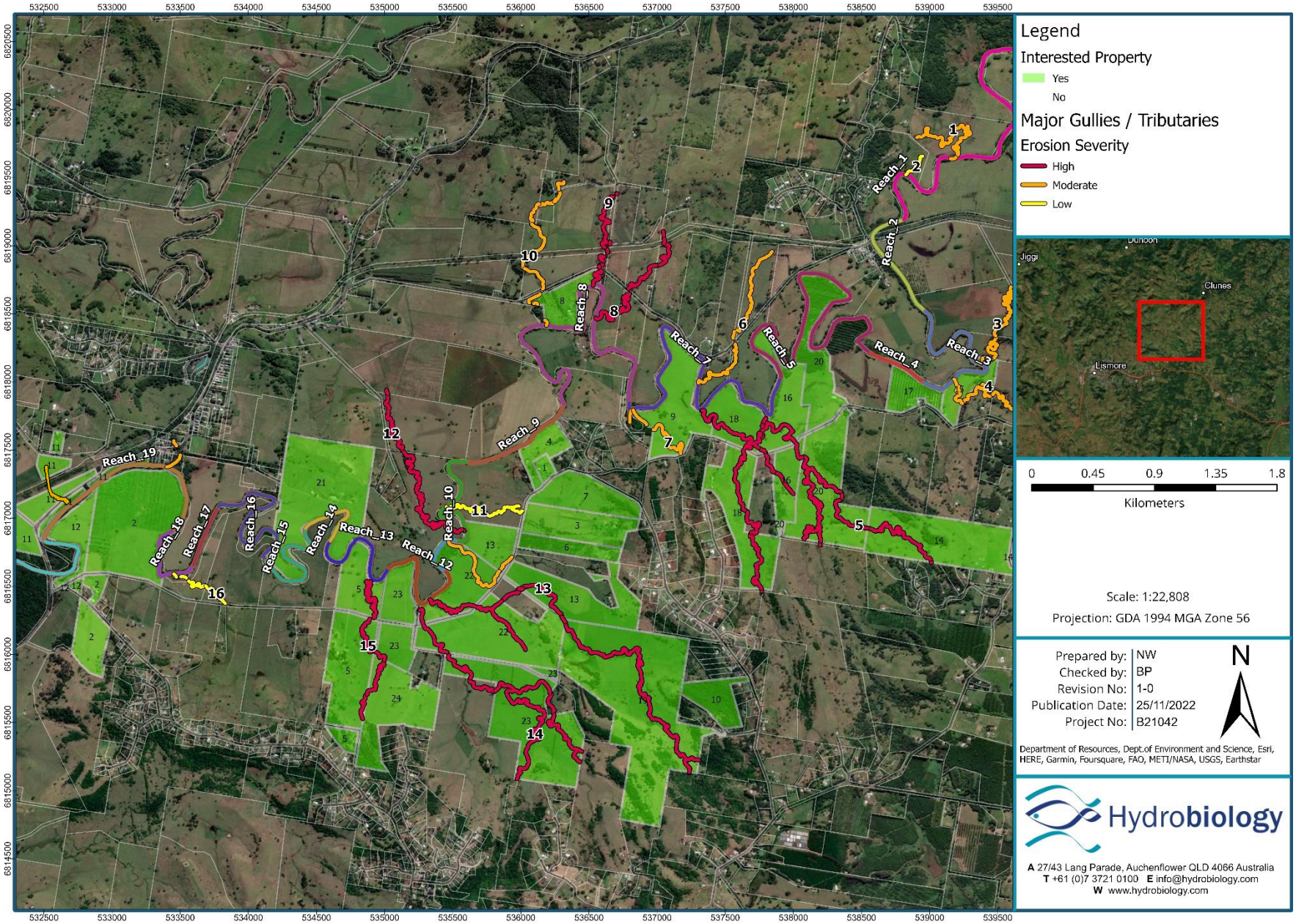


Figure 3-27 Severity of contributing gullies within the study reach. Gullies are numbered and overlaid on interested properties

3.2.3.3 SUB-REACH 1

CONDITION SUMMARY

Photographs showing features of Sub-Reach 1 are shown in Appendix C. In general, the sub-reach consisted of a highly incised slot channel with toe scour erosion, suggesting possible incision and headward erosion of the main channel. The geomorphic units consisted of long uniform runs, with some riffles and potentially headcuts. Considerable large woody debris (LWD) was present in the channel and there were few weed species, however there was patchy riparian cover (high level of clearing). There was widening in places from the recent flood, as well as risk of a potential avulsion at one location. Stock exclusion was non-existent, with cattle accelerating bank erosion. Headward eroding gullies (e.g., Gully 1) incising to the main channel bed level were evidence of main channel incision and such gullies form a major sediment source to the channel (Appendix C).

In terms of River Styles geomorphic condition, channel attributes were in Moderate condition with bank morphology showing signs of channel expansion. There was some wood in the channel and some instream vegetation (e.g., macrophytes), but this was limited. In terms of channel planform, the channel was laterally unstable, with widening occurring, toe scour, bank slumping, scour at bends and bed incision. There were limited geomorphic units, consisting of mainly long uniform pools, runs, with some LWD but a lack of bar features. There was also limited riparian vegetation, with patchy bank cover and no cover on the floodplain. Channel planform was therefore considered to be in Poor condition. Bed character was in Moderate condition, with the fine grain size appropriate for the River Style, but an unstable bed, with evidence of channel degradation. There was also a lack of hydraulic diversity with uniform runs. Overall, the sub-reach was ranked as being in Moderate-Poor geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (70).
- Habitat diversity score: High.
- Sub-reach included the following habitat:
  - Undercut banks.
  - Root masses.
  - Overhanging vegetation.
  - Macrophytes.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Moderate.
- Woody debris density: Moderate.
- Riparian clearing: High.
- Weed presence: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic Issues:
  - Headward eroding gullies.
  - Headcuts/Incision.
  - Potential avulsion location.
- Habitat issues:

  - Moderate lack of instream structure provided by woody debris.
- Bank Vegetative Stability:
  - A moderate level of bank stability provided by Lomandra.

3.2.3.4 SUB-REACH 2

CONDITION SUMMARY

Photographs showing features of Sub-Reach 2 are shown in Appendix C. Sub-Reach 2 consisted of long straights with runs and pools and lacking in diversity. There was toe scour, undercutting of banks and channel widening, particularly downstream of the Eltham Bridge crossing. Riparian cover was patchy, with the left bank being more cleared of vegetation.

In terms of River Styles geomorphic condition, channel attributes were in Moderate condition, with widening and toe scour of the banks. There was some LWD present and some potential for recruitment, but no instream vegetation present. In term of channel planform, the channel was considered to be laterally unstable with bank erosion and widening occurring throughout the sub-reach since the floods. Geomorphic units were lacking in diversity, consisting of mainly uniform runs and pools. There was continuous riparian cover on the banks and some on the floodplains and low weed coverage. Channel planform was therefore considered to be in Moderate condition. Bed character was also considered to be in Moderate condition, with appropriate bed material, however an unstable bed, with evidence of incision and widening. There was also a lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (77).
- Habitat diversity score: Moderate.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: High.
- Woody debris density: High (0.000135/m^2).
- Riparian clearing: Low.
- Weed coverage: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Channel widening.
- Habitat issues:
  - No obvious issues. Woody debris provides a relatively high amount of in-stream structure.
- Bank Vegetative Stability:
  - No obvious issues. Relatively high levels of Lomandra are providing stability to banks.

3.2.3.5 SUB-REACH 3

CONDITION SUMMARY

Photographs showing features of Sub-Reach 3 are shown in Appendix C. Sub-Reach 3 was more sinuous than the upstream reaches and was more diverse at bends due to increased hydraulic diversity and resulting increases in habitat types. In addition, LWD created riffles and some island features. However, there was considerable bank scour present throughout the sub-reach and two Moderate Risk, poorly vegetated, headward eroding gullies with aggradation at their confluences.

In terms of River Styles geomorphic condition, channel attributes were in Good condition despite poor bank morphology with eroding toe and bank scour, largely attributable to the considerable presence of LWD and instream vegetation. In terms of channel planform, however, the channel was laterally unstable with widening occurring throughout the sub-reach. Geomorphic units were more diverse than previous sub-reaches with runs, pools (often created at bends), islands, logs jams and LWD creating riffles. However, riparian cover was still patchy (Moderate clearing) on the banks, with no cover on the floodplain. Low weed coverage was observed despite the patchy riparian cover. Therefore, channel planform was in Poor condition. Bed character was in Moderate condition, with appropriate fine grained bed material but the bed had undergone incision, as evidenced by bank cracking, toe scour and the potential presence of headcuts migrating upstream via headward erosion processes. More hydraulic diversity was present compared to other sub-reaches. Overall, the sub-reach was ranked as being in Moderate geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (74).
- Habitat diversity score: Moderate.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: High.
- Woody debris density: High.
- Riparian clearing: Moderate.
- Weed presence: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic Issues:
  - Widening.
  - Bank Scour.
  - Headward eroding gullies.
- Habitat issues:
  - No obvious issues. Woody debris provides a relatively high amount of in-stream structure.
- Bank Vegetative Stability:
  - No obvious issues. Relatively high levels of Lomandra are providing stability to banks.

3.2.3.6 SUB-REACH 4

CONDITION SUMMARY

Photographs showing features of Sub-Reach 4 are shown in Appendix C. Sub-Reach 4 was less diverse than Sub-Reach 3 due to its lower sinuosity. The sub-reach consisted of long straight uniform runs, with localized riffle diversity resulting from log jams. The sub-reach had widespread toe scour, suggesting widening and vertical incision since the floods.

In terms of geomorphic condition, channel attributes were in Moderate condition, with bank morphology unstable (due to the toe scour mentioned above). In-channel woody debris was widespread throughout the sub-reach, with log jams but no instream vegetation. In terms of channel planform, the channel was laterally unstable with toe scour, some widening and possible incision. Geomorphic units were lacking in diversity with long uniform runs and pools and LWD but no bars or island features. There were some inset benches present and some riparian vegetation on the banks, but cover was patchy (High riparian clearing) and dominated by weeds, and there was no cover on the floodplain. Channel planform was therefore considered to be in Poor condition. Bed character was Moderate condition, with appropriate bed material however the bed was not vertically stable with potential incision. There was also a lack of hydraulic diversity with uniform runs. Overall, the sub-reach was ranked as being in Moderate-Poor condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Fair (64).
- Habitat diversity score: Low.
- Sub-reach includes:
  - Root masses.
  - Overhanging vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: High.
- Riparian clearing: High.
- Weed presence: Moderate.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic Issues:
  - Incision.
  - Widening.
- Habitat issues:
  - Lacking some habitat diversity, however the large amount of woody debris present provides considerable in-stream structure.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra, poor riparian cover and dominant exotic species.

3.2.3.7 SUB-REACH 5

CONDITION SUMMARY

Photographs showing features of Sub-Reach 5 are shown in Appendix C. Sub-Reach 5 was a similar channel type to the previous sub-reaches, although some variability was present depending on the riparian cover and bank type. More habitat diversity was observed at bends compared to straight sections. However, there were extensive bank exposures on bends, with potential avulsion risks.

In terms of River Styles geomorphic condition, channel attributes were in Moderate condition, with toe scour and widening evident in the bank morphology. Although there was widespread LWD present in the channel, there was a general lack of instream vegetation. In terms of channel planform, the channel was unstable, with evidence of bank collapse, toe scour, widening and potential avulsion risk. There was also a lack in geomorphic unit diversity, with mostly long runs, glides, pools and only some riffles induced by LWD. Vegetation cover was patchy in the riparian zone and non-existent on the floodplain, with moderate weed presence. Therefore, channel attributes were in poor condition. Bed character was in Moderate condition, with bed material appropriate for the River Styles type, however the bed was not vertically stable with potential incision occurring. There was also a lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate-Poor condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (74).
- Habitat diversity score: Moderate.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Moderate.
- Woody debris density: High.
- Riparian clearing: Low.
- Weed presence: Moderate.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic Issues:
  - Erosion and bank exposures at bends.
  - Widening.
  - Incision.
  - Avulsion risk.
- Habitat issues:
  - Lacking some habitat diversity, however the large amount of woody debris present provides for healthy in-stream structure.
- Bank vegetative stability issues:
  - A moderate level of bank stability provided by Lomandra.

3.2.3.8 SUB-REACH 6 AND 7

CONDITION SUMMARY

Photographs showing features of Sub-Reach 6 and 7 are shown in Appendix C. The sub-reach was sinuous and comprised generally stable banks, with erosion highly localized at bends. There was also a high potential avulsion risk across the floodplain where there is currently a preferential flood flow path (Figure 3-20). Here, there was a large bank exposure at the upstream bend and gullying into the floodplain where the preferential flood flow path re-joins the channel. The landowners acknowledged the high potential for avulsion at this location. In addition to the avulsion risk, a number of gullies with large catchments (Gullies 5, 6, 7) meet the study reach within Sub-Reaches 6 and 7. These are generally poorly vegetated and are experiencing upstream migration of headcuts that have the potential to result in further catchment degradation and sediment input into the main river.

In terms of River Styles, channel attributes were considered to be in Moderate condition with large bank exposures at bends and potential avulsion risk. Although there was widespread LWD observed in the channel creating diversity, there was a lack of instream vegetation. Channel planform was in Poor condition, with the channel laterally unstable due to bank erosion and avulsion risk. There was also a lack of geomorphic units with mostly long runs and pools. The channel was wider compared to upstream sub-reaches and LWD was generating some riffle diversity. Although there was riparian cover on the banks, there was significant riparian clearing and the riparian zone was dominated by exotics. There was also no cover on the floodplain, particularly in areas of avulsion risk. Bed character was considered to be in Moderate condition, with the bed material appropriate for the River Style but a potential unstable bed with some incision and potential headcuts. There was also a lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate-Poor condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Fair (65).
- Habitat diversity score: Moderate.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Moderate.
- Woody debris density: High.
- Riparian clearing: High.
- Weed presence: High.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Erosion at bends.
  - High avulsion risk.
  - Potential headcuts.
  - Headward eroding gullies.
  - Poorly vegetated, large catchment providing considerable sediment inputs.
- Habitat issues:

  - Lacking some habitat diversity, however the large amount of woody debris present provides lots of in-stream structure.
- Bank vegetative stability issues:
  - A moderate level of bank stability provided by Lomandra.
  - Lack of continuous riparian zone and high presence of weeds.

3.2.3.9 SUB-REACH 8

CONDITION SUMMARY

Photographs showing features of Sub-Reach 8 are shown in Appendix C. The sub-reach was a similar channel type to previous sub-reaches but had some localized diversity associated with bedrock outcropping. At the upstream extent of the sub-reach, the channel abuts the valley margin in places and there is bedrock outcropping in places, with bedrock steps and headcuts that add hydraulic diversity. Bedrock appears to be controlling bed level at this point and suggests that further incision is unlikely through this sub-reach. The sub-reach then transitions back to uniform runs and deep pools that lack habitat diversity, with banks that are in poor condition due to no riparian vegetation and no stock exclusion. Several sediment producing gullies (Gully 8, 9, 10) that drain poorly vegetated catchments and are experiencing eroding headcuts as a result of the incision discussed above.

In terms of River Styles geomorphic condition, channel attributes were in Good condition despite scour present, due to the widespread LWD, and the observed instream vegetation (e.g., macrophytes). Channel planform, however, was in poor condition, with evidence of lateral instability throughout. Although there was good diversity of geomorphic units in the upstream part of the sub-reach, such as riffles, pools and LWD, this was lacking in the downstream section of the sub-reach, where runs dominated . There was also a lack of riparian vegetation cover (Moderate clearing) and a prominence of weed species. Bed character was considered to be in Moderate condition, with bed material consisting of bedrock outcropping and fine-grained material appropriate to the River Style. A headcut was evident in the upstream section of the sub-reach with associated incision, although the bedrock will limit any further upstream headcut migration and associated deepening. There was good hydraulic diversity associated with bedrock outcropping, but these outcrops were interspersed by uniform runs. Overall, the sub-reach was ranked as being in Moderate geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (80).
- Habitat diversity score: High.
- Sub-reach includes:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Macrophytes.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: Low.
- Riparian clearing: Moderate.
- Weed presence: High.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Bedrock steps / Headcuts – point of upstream channel incision.
  - Headward eroding gullies.
  - Poorly vegetated, large catchment providing considerable sediment inputs.
- Habitat issues:
  - Lack of woody debris obvious, low amount of in-stream habitat.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra.
  - Moderate level of riparian clearance and high prominence of weed species.

3.2.3.10 SUB-REACH 9

CONDITION SUMMARY

Photographs showing features of Sub-Reach 9 are shown in Appendix C. The sub-was narrower and less incised than other sub-reaches and was generally in poor condition. This was due to a lack of habitat diversity and no riparian cover resulting in bank scour and failures throughout. Regardless of the limited habitat diversity, turtles were observed in several locations in this sub-reach.

In terms of River Styles geomorphic condition, channel attributes and planform were considered to be in Poor condition, with bank slumping and failures (and resulting lateral instability) throughout the sub-reach due to the lack of vegetative cover on both banks and floodplain. The absence of riparian vegetation and prominence of weeds also resulted in a lack of woody debris and would result in a very low potential for wood recruitment. There was also no instream vegetation. There was also a lack of geomorphic units with only uniform runs and pools, with no habitat diversity. Bed character was in Moderate condition, with the bed material appropriate to the River Style but vertically unstable with some incision evident (less prevalent than upstream). There was limited hydraulic diversity. Overall, the sub-reach was ranked as being in Poor condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Fair (54).
- Habitat diversity score: Low.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: Low.
- Riparian clearing: High.
- Weed presence: High.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Poor condition / Lack of habitat diversity / No riparian.
  - Bank slumping and scour.
- Habitat issues:

  - Lack of habitat diversity and low levels of woody debris obvious, low amount of in-stream habitat.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra.
  - Prominence of weed species in a highly disturbed riparian zone.

3.2.3.11 SUB-REACH 10

CONDITION SUMMARY

Photographs showing features of Sub-Reach 10 are shown in Appendix C. This sub-reach was to Sub-Reach 9 but with slightly more diversity due to bends generating hydraulic diversity. In terms of River Styles geomorphic condition, channel attributes and planform were in Moderate to Poor condition, with lateral instability (toe scour, bank slumping) where there was no vegetation. Riparian vegetation was patchy (High clearing, moderate weed coverage) throughout the sub-reach. Although there was some LWD, the channel was lacking in instream vegetation. There was limited geomorphic units with only uniform runs and pools, some riffles but mostly lacking habitat diversity. Bed character was considered to be in Moderate condition, with fine grained bed material appropriate to the River Style, but the bed was vertically unstable, with toe collapse, scour and perched tributaries (Gullies 11, 12) indicative of main channel incision. These perched tributaries have the potential to further develop, with incision and widening (channel expansion) likely in response to the main channel bed incision, particularly given the absence of vegetation within the gully riparian zone and catchments. Overall, the sub-reach was ranked as being in Moderate-Poor geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (71).
- Habitat diversity score: Moderate.
- Sub-reach includes:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: Moderate.
- Riparian clearing: High.
- Weed presence: Moderate.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues
  - Bank slumping and scour.
  - Expansion of perched tributaries and sediment delivery to the channel.
- Habitat issues:
  - Moderate lack of instream structure provided by woody debris.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra.
  - Distinct lack of riparian zone through much of the reach.

3.2.3.12 SUB-REACH 11

CONDITION SUMMARY

Photographs showing photos of Sub-Reach 11 are shown in Appendix C. The sub-reach had marginally more habitat than Sub-Reach 9 and 10 due to a greater LWD input and flood debris from the left bank creating some habitat diversity. However, there is still widespread bank scour throughout the sub-reach. A small, perched, poorly vegetated gully drains into the reach (Gully 11a).

In terms of River Styles geomorphic condition, channel attributes were rated as Moderate condition with the bank morphology experiencing toe scour and bank failures. Despite the LWD and flood debris, no instream vegetation was present. In terms of channel planform, the channel was laterally unstable with some scour. Geomorphic units were lacking in diversity, consisting mainly of uniform pools and runs with some LWD creating riffles. There was riparian cover on the left bank but none on the bank toe, no cover on the floodplain and noticeable presence of weed species. Therefore, channel planform was in Poor condition. Bed character was in Moderate condition, with fine grained bed material and some bed incision evident from bank scour and bank collapse. In general, there was a lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate-Poor condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (73).
- Habitat diversity score: Low.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Moderate.
- Woody debris density: Moderate.
- Riparian clearing: High.
- Weed presence: Moderate.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Bank slumping and scour.
  - Small tributary inputs.
- Habitat issues:
  - Moderate lack of instream structure provided by woody debris.
- Bank vegetative stability issues:
  - A moderate level of bank stability provided by Lomandra.
  - Poor riparian vegetation providing little added bank stability.

3.2.3.13 SUB-REACH 12

CONDITION SUMMARY

Photographs showing photos of Sub-Reach 12 are shown in Appendix C. The sub-reach had several tributaries (Gully 13, 14) that flowed into this sub-reach, resulting in island and riffle diversity, with localized deposition from tributary sediment inputs resulting in isolated shallow sections and

concomitant macrophytes and instream vegetation. As noted above, turbidity around the confluences was notably higher than that of the main Wilsons River channel.

Several potential headcuts were observed, suggesting upstream incision, with a single perched tributary supporting this observation. In addition to greater habitat diversity, there was marginally more riparian vegetation cover than surrounding sub-reaches (moderate clearing), although it was generally patchy, dominated by exotic species, and occurred higher up the bank with poorly vegetated bank toes resulting in scour and bank failure (cantilever failure).

In terms of River Styles geomorphic condition, channel attributes were in Moderate condition, with banks eroding with scour and some failures. The presence of some LWD and instream vegetation (e.g., macrophytes) noted above improved this rating. In terms of channel planform, the channel was rated as unstable, due to the noted scour and bank failures. There was some geomorphic unit diversity associated with tributary inputs resulting in island formation, riffles, pools and LWD. Bed character was in Moderate condition. The noted headcuts within the channel had resulted in deepening and had led to headward erosion and incision of the tributaries. There was some local hydraulic diversity associated with the tributary inputs. Overall, the sub-reach was ranked as being in Moderate geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (71).
- Habitat diversity score: Moderate.
- Sub-reach included:
  - Undercut banks.
  - Overhanging Vegetation.
  - Macrophytes.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: Moderate.
- Riparian clearing: Moderate.
- Weed presence: High.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Potential headcuts.
  - Scour.
  - Tributaries headward eroding / sediment input.
- Habitat issues:
  - Moderate lack of instream structure provided by woody debris.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra.
  - Poor riparian condition, including weed dominance.

3.2.3.14 SUB-REACH 13

CONDITION SUMMARY

Photographs showing features of Sub-Reach 13 are shown in Appendix C. There was widespread bank slumping and toe scour in areas where vegetation was absent, similar to upstream. Incision appeared to be less than compared to upstream sub-reaches, although a headward eroding tributary (Gully 15) suggested that past incision may have occurred. This gully drained a large, poorly vegetated catchment and was evidently contributing sediment to the river.

In terms of River Styles geomorphic condition, channel attributes were in Moderate condition, attributable to the bank slumping and toe scour noted above. The absence of riparian vegetation had resulted in little presence of LWD and infestation of weeds. Channel planform was in Poor condition, largely due to the lateral instability (bank failures) noted above. There was also a lack of geomorphic unit diversity with the sub-reach characterised by long uniform runs, pools and depauperate habitat. Bed character however was in relatively Good condition, with the sub-reach characterised by more stable bed features and less incision compared to upstream. Overall, the sub-reach was ranked as being in Moderate condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (73).
- Habitat diversity score: Low.
- Sub-reach included:
  - Undercut banks.
  - Macrophytes.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: Moderate.
- Riparian clearing: High.
- Weed presence: Moderate.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Bank Slumping.
  - Toe Scour.
  - Headward eroding gully.
- Habitat issues:
  - Low level of habitat diversity and a moderate lack of instream structure provided by woody debris.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra.
  - Clearance of riparian zone.

3.2.3.15 SUB-REACH 14

CONDITION SUMMARY

Photographs showing features of Sub-Reach 14 are shown in Appendix C. There was widespread bank scour associated with poor riparian vegetation, the effects of the floods and a general lack of geomorphic diversity. In terms of River Styles geomorphic condition, channel attributes were in Poor condition with bank morphology poor with some scour and no woody debris or instream vegetation in the channel. Channel planform was considered to be in Moderate condition, attributable to the lack of geomorphic unit diversity with mostly long runs with no bar features and a lack of riparian cover. Bed character was also in poor condition, with widespread bed instability driven by headcuts and incision. Overall, the sub-reach was rated as being in Moderate-Poor geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Fair (58).
- Habitat diversity score: High.
- Sub-reach includes:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Macrophytes.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: Low.
- Riparian clearing: High.
- Weed presence: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Bank scour.
  - Lack of geomorphic diversity.
- Habitat issues:
  - Lack of woody debris obvious, low amount of in-stream habitat.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra.
  - Riparian vegetation clearance.

3.2.3.16 SUB-REACH 15

CONDITION SUMMARY

Photographs showing features of Sub-Reach 15 are shown in Appendix C. There was widespread bank scour associated with the floods and a general lack of geomorphic and associated habitat (e.g., riffles, pools, etc.) diversity. In terms of River Styles geomorphic condition, channel attributes were in Moderate condition with poor bank morphology, no instream vegetation, and isolated LWD. Channel planform was in Poor condition, with the channel being laterally unstable. There was also a general lack of geomorphic units, a lack of riparian cover, and moderate presence of weeds. Bed character

was also in Moderate condition, with the bed material appropriate for the River Style, the channel comprising an unstable bed (some incision), and a general lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate-Poor geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Fair (61).
- Habitat diversity score: High.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging vegetation.
  - Macrophytes.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: Low.
- Riparian clearing: High.
- Weed presence: Moderate.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Incision.
  - Scour.
- Habitat issues:
  - Low level of in-stream structure. Lack of woody debris obvious.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra.
  - Significant clearance of riparian vegetation and dominance of exotic species.

3.2.3.17 SUB-REACH 16

CONDITION SUMMARY

Photographs showing features of Sub-Reach 16 are shown in Appendix C. There was widespread bank scour associated with recent floods and a general lack of geomorphic and habitat diversity. In terms of River Styles geomorphic condition, channel attributes were in Moderate condition with poor bank morphology but some LWD and no instream vegetation. Channel planform was in Poor condition, due to the noted bank scour and resulting lateral instability. There was also limited geomorphic unit diversity, lack of riparian cover, and dominance of weed species. Bed character was also in Moderate condition, with the bed material appropriate for the River Style but with potential incision and resulting lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate-Poor geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Fair (65).
- Habitat diversity score: Moderate.

- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: High.
- Woody debris density: Low.
- Riparian clearing: High.
- Weed presence: Moderate.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Incision.
  - Scour.
- Habitat issues:
  - Lack of woody debris obvious, low amount of in-stream habitat.
- Bank Vegetative Stability:
  - Relatively high levels of Lomandra are providing stability to banks.
  - Significant clearance of trees within riparian zone and encroachment of weed species.

3.2.3.18 SUB-REACH 17

CONDITION SUMMARY

Photographs showing features of Sub-Reach 17 are shown in Appendix C. The banks were in better condition compared to Sub-Reach 15 and 16, largely attributable to the increased complexity of the riparian zone, however habitat was still lacking within the channel. In terms of River Styles geomorphic condition, channel attributes were in good condition, with bank morphology intact and widespread LWD and high potential for wood recruitment. However, there was still a lack of instream vegetation. Channel planform was in Moderate condition, with high lateral stability but low diversity in geomorphic units, with habitat dominated by runs. Bed character was also in Moderate condition, with fine grained bed material appropriate for the River Style and a mostly stable bed. However, there was still a lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (70).
- Habitat diversity score: Low.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: High.
- Woody debris density: Moderate.

- Riparian clearing: Low.
- Weed presence: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Lack of habitat.
- Habitat issues:
  - Low level of habitat diversity and instream structure. Little woody debris present.
- Bank vegetative stability issues:
  - Bank stability affected by a lack of Lomandra, but greater riparian overstorey vegetation integrity contributing to increased stability.

3.2.3.19 SUB-REACH 18

CONDITION SUMMARY

Photographs showing features of Sub-Reach 18 are shown in Appendix C. The channel was characterised by poor habitat and widespread bank failures associated with a lack of riparian vegetation. A single perched tributary (Gully 16) was observed that was contributing sediment to the channel and affecting in-stream water quality. In terms of River Styles geomorphic condition, channel attributes were in Moderate condition, due to some bank failures, a lack of instream vegetation, and the presence of LWD (and flood debris). Channel planform was in Poor condition due to the noted lateral instability, the lack of habitat diversity (uniform runs and pools no islands or riffles). Vegetation was patchy within the riparian zone, although there were some well vegetated stretches, while trees were non-existent on the floodplain. Bed character was however considered to be mostly in Good condition, with the bed material appropriate for the River Style and no evidence of bed instability. However, there was a general lack of hydraulic diversity. Overall, the sub-reach was ranked as being in Moderate geomorphic condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Fair (64).
- Habitat diversity score: Moderate.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: High.
- Riparian clearing: High.
- Weed presence: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Lack of habitat.

  - Headward eroding gully.
- Habitat issues:
  - Lacking some habitat diversity, however the large amount of woody debris present provides considerable in-stream structure.
- Bank vegetative stability issues
  - Low level of bank stability due to a lack of Lomandra and riparian overstorey.

3.2.3.20 SUB-REACH 19

CONDITION SUMMARY

Photographs showing features of Sub-Reach 19 are shown in Appendix C. Habitat was of better quality in this sub-reach compared with surrounding reaches due to the greater LWD input and good overhanging vegetation. The riparian vegetation also resulted in more stable bank morphology, with less erosion evident and only occurring in isolated patches of no riparian vegetation. A small headward eroding gully was observed to be contributing sediment to the channel, with bank failures occurring at its confluence. This increased sediment load was affecting turbidity within the main channel in and around the confluence.

In terms of River Styles geomorphic condition, channel attributes were in Moderate condition, with some scour evident but less compared to upstream. There was also more LWD input, but there was still a lack of instream vegetation. Channel planform was in Good condition, with the channel mostly stable, with less scour and erosion compared to upstream. There was also a good diversity of geomorphic units with riffles from LWD, pools and runs, widespread overhanging riparian vegetation, and few weed species. Bed character was in Moderate condition, with some degradation of minor undercut banks but good diversity in hydraulic conditions. Overall, the sub-reach was ranked as being in Good-Moderate condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (79).
- Habitat diversity score: Moderate.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Moderate.
- Woody debris density: High.
- Riparian clearing: Low.
- Weed presence: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Undercut banks.
  - Headward eroding gully.
- Habitat issues:

  - Lacking some habitat diversity, however the large amount of woody debris present provided considerable in-stream structure.
- Bank vegetative stability issues:
  - A moderate level of bank stability provided by Lomandra and continuous stretches of riparian vegetation.

3.2.3.21 SUB-REACH 20

CONDITION SUMMARY

Photographs showing features of Sub-Reach 20 are shown in Appendix C. Habitat was of similar quality to Sub-Reach 19, due to the quality of riparian vegetation and wood loading associated with the adjacent Boat Harbour Nature Reserve. There was more LWD input and good overhanging vegetation, with the sub-reach being in similar condition to Sub-Reach 19.

In terms of River Styles geomorphic condition, channel attributes were in good condition, with less scour due to the greater presence of riparian vegetation and fewer weed species. There was also considerable LWD and instream vegetation (e.g., macrophytes). Channel planform was in Moderate condition, as the channel was more laterally stable than other sub-reaches. However, there was still limited geomorphic unit diversity, with mostly uniform runs and pools, with missing riffle and hydraulic diversity. This was most likely due to previous headcut migration and associated incision. The presence of dense riparian vegetation noted above improved planform condition.

Bed character was in Good condition, with the fine-grained bed material appropriate for the River Style and the bed relatively stable compared to other sub-reaches. Although, there was still a lack of hydraulic diversity with uniform flow (again likely due to previous incision). Overall, the sub-reach was ranked as being in Good-Moderate condition.

HABITAT

The habitat site assessment can be summarized as follows:

- Habitat bioassessment score: Good (91).
- Habitat diversity score: High.
- Sub-reach included:
  - Undercut banks.
  - Root masses.
  - Overhanging Vegetation.
  - Macrophytes.
  - Lomandra.
  - Woody debris.
- Lomandra coverage: Low.
- Woody debris density: High.
- Riparian clearing: Low.
- Weed presence: Low.

ISSUES

The key issues within the sub-reach can be summarized as follows:

- Geomorphic issues:
  - Minor bank scour.
- Habitat issues:
  - High habitat diversity. Large amount of woody debris present provides considerable in-stream structure.

- Bank vegetative stability issues:
  - Lack of Lomandra affecting toe stability, but greater presence of trees providing additional stability.

3.3 SUMMARY OF ISSUES AND OVERLAP WITH INTERESTED PROPERTIES

In general, it was found that the upper reaches of the Wilsons River Study reach were more greatly impacted by the recent February 2022 floods, affecting both the current geomorphic and ecological condition. This is mostly due to the upper reach having undergone headcut migration, channel incision and widening, due to a meander cut-off in Sub-Reach 8, with the migration of headcuts upstream of this accelerated by the floods. As a result, less incision was observed downstream, however there was also a lack of instream habitat observed in Sub-Reach 9 and Sub-Reach 12-17. Regardless, there appeared to be several active issues occurring throughout the study reach that threaten its integrity. This includes:

- There appeared to be a history of incision throughout the reach of varying ages. Obvious deepening, toe scour, uniform flow conditions and geomorphic units, old meander cutoffs, and perched tributaries through much of the length of the study reach provided strong evidence of this.
- Active headcuts were observed in several sub-reaches driven by previous meander cutoffs. These will continue to migrate upstream (unless halted by bedrock, as in Sub-Reach 8) and cause channel deepening and widening.
- Previous meander cutoffs have caused considerable changes to the channel. Several locations exist throughout the study reach where future avulsion risk remains high, including paleochannels, locations where meander migration presents a potential for future meander cutoffs, low points in the floodplain, and tributary inflows.
- Incision has resulted in perched tributaries (mostly gullies) where bed level is above the bed level of the main channel (i.e., headcut). These now appear to be further developing, with upstream migration of the headcut apparent in several gullies and increased sediment delivery (both bedload and suspended) to the channel evident in some sub-reaches. While this has resulted in more variable geomorphic units in some locations, continued headcut migration will result in further increases in fine sediment delivery (and associated water quality impacts) within the main channel, particularly those gullies draining catchments with limited vegetation cover and poor riparian zone condition.
- A distinct lack of riparian and floodplain vegetation has exacerbated many of the above issues and will continue to increase the risk of lateral migration, meander cutoffs, avulsions, gully development, and deterioration of habitat quality.

Given the above summary and the detailed reach-by-reach assessment, several sub-reaches were identified as higher priority focus for management. These were Sub-Reach 1, 4, 5-9 and 13-17, with overlap with interested property owners shown in Figure 3-28. Sub-Reaches 5-9 consist of mostly geomorphic issues such as major bank erosion, headcut migration, incision, channel widening and avulsion risk; while Sub-Reach 9, and 13 – 17 are mainly lacking in instream ecological habitat (although geomorphic issues are still present). These reaches were identified as higher priority because:

- There are a greater number of issues present, including both geomorphic (e.g., bank scour, headcut, etc.) and habitat (e.g., riparian cover, in-stream habitat issues) issues.
- A lack of management of the issues present will result in degradation of both the reaches in the immediate vicinity but also upstream and downstream reaches (e.g., through meander cutoff).

While the lower priority reaches still have issues that will need addressing, it is advised to approach these subsequent to the higher priority reaches.

As outlined above, the mapped headward eroding gullies and tributaries that are adjusting to the new incised base level of Wilsons River are also a main priority as they were noted during the site visit to

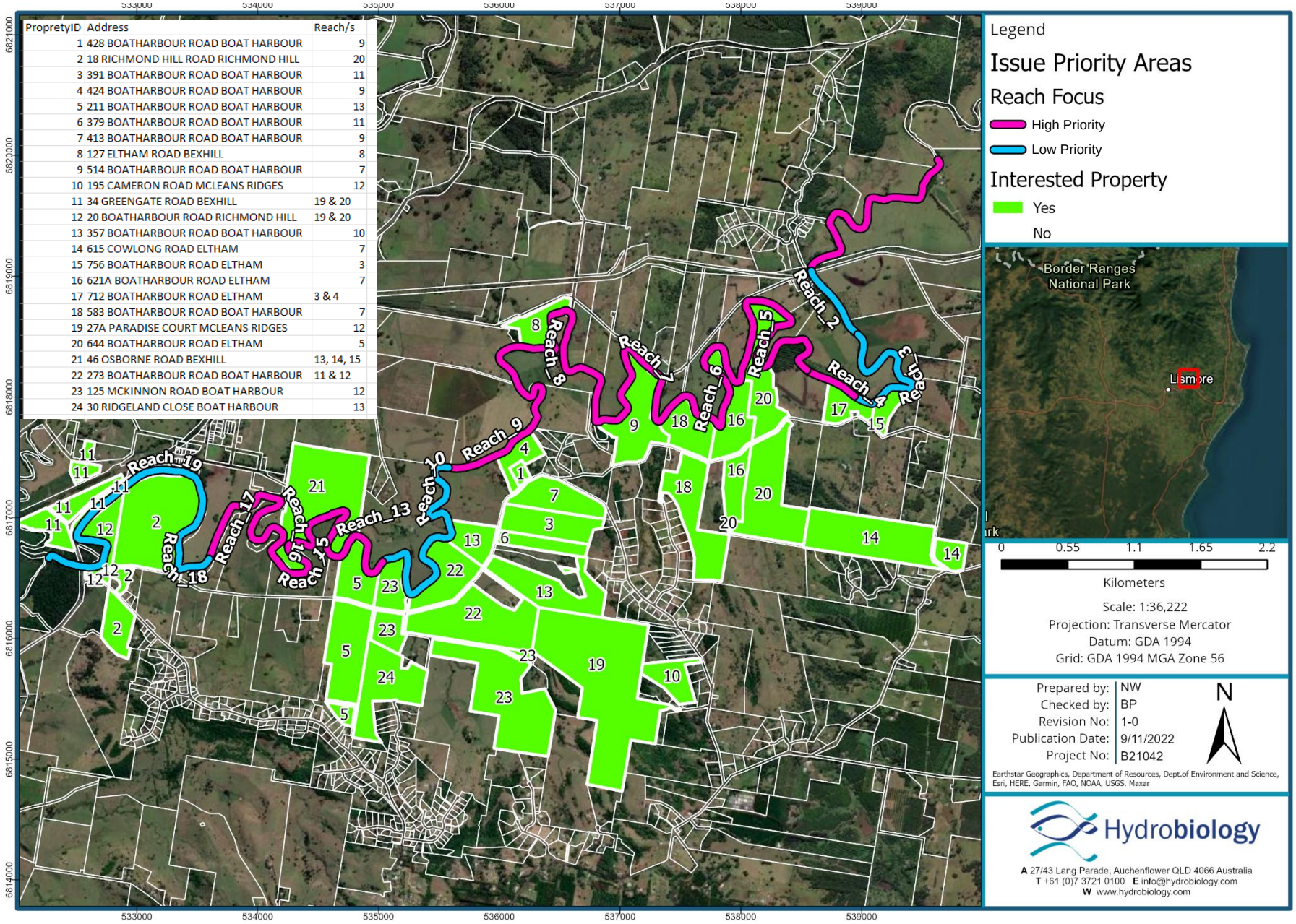
be providing a large sediment source. As noted above, these are occurring in Sub-Reaches 1, 3, 6/7, 8, 10-13, 18, and 19 and will require catchment management focus in addition to riverine management actions.

A summary of the issues within each of these priority sub-reaches are as follows:

- **Sub-Reach 1:**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
    - Headcuts/Incision.
    - Potential avulsion location.
  - Habitat issues:
    - Moderate lack of instream structure provided by woody debris.
  - Bank Vegetative Stability:
    - A moderate level of bank stability provided by Lomandra.
- **Sub-Reach 3:**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
- **Sub-Reach 4:**
  - Geomorphic Issues:
    - Incision.
    - Widening.
  - Habitat issues:
    - Lacking some habitat diversity, however the large amount of woody debris present provides considerable in-stream structure.
  - Bank vegetative stability issues:
    - Low level of bank stability due to a lack of Lomandra, poor riparian cover and dominant exotic species.
- **Sub-Reach 5 to Sub-Reach 8:**
  - Geomorphic Issues:
    - Major erosion and bank exposures at bends.
    - Widening.
    - Potential headcuts, with point of upstream incision from Sub-Reach 8.
    - Incision.
    - High avulsion risk.
    - Headward eroding/perched gullies draining poorly vegetated catchments.
  - Habitat issues:
    - Lacking some habitat diversity, however the large amount of woody debris present provides considerable in-stream structure, except for Sub-Reach 8 that lacks woody debris.
  - Bank vegetative stability issues:
    - Moderate bank stability provided by Lomandra, except for Sub-Reach 8 that has a low level of bank stability due to a lack of Lomandra.
    - Lack of continuous riparian zone and high presence of weeds.
- **Sub-Reach 9:**
  - Geomorphic issues:
    - Poor condition / Lack of habitat diversity / No riparian cover.

  - Bank slumping and scour.
- Habitat issues:
  - Lack of habitat diversity and little LWD, poor in-stream habitat.
- Bank vegetative stability issues:
  - Low level of bank stability due to a lack of Lomandra. No riparian habitat.
  - Prominence of weed species in a highly disturbed riparian zone.

- **Sub-Reach 10-11**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
- **Sub-Reach 12:**
  - Geomorphic issues:
    - Potential headcuts.
    - Scour.
    - Headward eroding gullies draining poorly vegetated catchments.
  - Habitat issues:
    - Moderate lack of instream structure provided by woody debris.
  - Bank vegetative stability issues:
    - Poor bank stability due to a lack of Lomandra.
    - Poor riparian condition, including weed dominance.
- **Sub-Reach 13 – 17:**
  - Geomorphic issues:
    - Minor incision.
    - Scour.
    - Lack of habitat.
  - Habitat issues:
    - Poor habitat diversity and a general lack of instream structure provided by woody debris.
  - Bank vegetative stability issues:
    - Poor bank stability due to a lack of Lomandra and significant riparian clearance, except for Sub-Reach 16 and 17.
- **Sub-Reach 18-19**
  - Geomorphic Issues:
    - Headward eroding gullies draining poorly vegetated catchments.
- **General issues related to mapped gullies/tributaries (locations described above):**
  - Issues:
    - Headward eroding and incision.
    - Produce large sediment (fine and coarse) source to main Wilsons River.
    - Affect water quality and habitat.
    - Degradation of upstream catchment and loss of farming land.



PropretyID	Address	Reach/s
1	428 BOATHARBOUR ROAD BOAT HARBOUR	9
2	18 RICHMOND HILL ROAD RICHMOND HILL	20
3	391 BOATHARBOUR ROAD BOAT HARBOUR	11
4	424 BOATHARBOUR ROAD BOAT HARBOUR	9
5	211 BOATHARBOUR ROAD BOAT HARBOUR	13
6	379 BOATHARBOUR ROAD BOAT HARBOUR	11
7	413 BOATHARBOUR ROAD BOAT HARBOUR	9
8	127 ELTHAM ROAD BEXHILL	8
9	514 BOATHARBOUR ROAD BOAT HARBOUR	7
10	195 CAMERON ROAD MCLEANS RIDGES	12
11	34 GREENGATE ROAD BEXHILL	19 & 20
12	20 BOATHARBOUR ROAD RICHMOND HILL	19 & 20
13	357 BOATHARBOUR ROAD BOAT HARBOUR	10
14	615 COWLONG ROAD ELTHAM	7
15	756 BOATHARBOUR ROAD ELTHAM	3
16	621A BOATHARBOUR ROAD ELTHAM	7
17	712 BOATHARBOUR ROAD ELTHAM	3 & 4
18	583 BOATHARBOUR ROAD BOAT HARBOUR	7
19	27A PARADISE COURT MCLEANS RIDGES	12
20	644 BOATHARBOUR ROAD ELTHAM	5
21	46 OSBORNE ROAD BEXHILL	13, 14, 15
22	273 BOATHARBOUR ROAD BOAT HARBOUR	11 & 12
23	125 MCKINNON ROAD BOAT HARBOUR	12
24	30 RIDGELAND CLOSE BOAT HARBOUR	13

Figure 3-28 Summary of focus priority sub-reaches identified and overlap with interested property owners for management within the Wilsons River Study Reach.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 SUMMARY OF ISSUES AND RECOMMENDED WORKS

A summary of each of the issues throughout the Wilsons Study Reach, associated recommendations, and identified priority sub-reaches are summarised below in Table 4-1. Table 4-2 the provides a property-by-property guide of potential restorative works to explore as part of the site-based action plans. These should be considered as preliminary ideas for discussion with all relevant stakeholders as part of the plan development, with some works (e.g., grade control, gully stabilisation, etc.) likely to require engineering input beyond the scope of this project and the site-based action plan premise. However, Table 4-2 provides a template from which to base discussions on going forward and will allow for effective plan development. While not part of the scope of this project, the River Styles mapping suggests that the condition of the upper reaches of Wilsons River (and tributaries) should also be focussed on in future projects to improve recovery potential for the whole catchment.

4.2 SITE BASED ISSUES

To inform the next stage of the project, issues specific to each property that has indicated interest in the project, and potential management measures for discussion, have been listed in Table 4-2. These mitigation measures are not provided as absolute solutions but to guide discussions in development of the Site Based Action Plans. It must be noted that of all the issues identified in Table 4-2, several

issues must be identified as higher priority due to the potential implications for reach-wide instability, downstream sediment load, and concomitant water quality decline. These issues are:

- Channel Avulsion / Meander cut-off.
- Channel Incision / Bank Collapse.
- Loss of Riparian (& ecotonal) vegetation.
- Gully development.

Table 4-1 Summary of river condition issues and recommended restoration works for specifc sub-reaches and properties.

River Condition Issue - & Causes	Restorative Works	Where / How? Strategic	Associated Field Work / Investigations	Specific Sub-Reaches / Properties Identified
• **Bank Erosion and Scalding Riparian vegetation clearance** **- Stock access to banks** **- Peakier flood events** **- Channel incision**	Stock exclusion fencing	• Grazing properties, particularly where bank condition is being impacted. • Consultation with landholders has identified that maintenance and not cost in the primary deterrent. • Funding of a fencing maintenance contractor that operated across the project reach may be a viable innovation?	• Scope broader endorsement of viable role for fencing maintenance contractor. • Identify number of Grazing properties in project reach lacking exclusion fencing. • Examine relative benefits / bank stability resulting from different types of vegetation cover that result from stock exclusion.	**All priority sub-reaches** where fencing is not in place
	Intensive revegetation	• Degraded / cleared banks that have lost natural regenerative capacity (i.e., no remnant overstorey). • Eroded bank areas not requiring more intensive engineered solutions (not as initial works but role post engineering). • Sites where revegetation can play greater geomorphic /ecological roles, (i.e., channel outbreak paths, projected pressure points in channel evolution, breaks in riparian vegetation connectivity)	• Identify, map out flood break out points, likely channel migration pressure points. • Develop prescriptive bank zone, flow inundation depth planting guides for different riparian species based on observed growth locations and past establishment success to ensure for effective use of resources.	Most needed in **Sub-Reach 5 – 9.**
	Intensive planting understorey Lomandra	• Bare / partially bare banks, lower toe of slopes, areas not subject to high erosive forces/ requiring preliminary engineered works. • Areas with existing mixed / partial vegetation cover that can be consolidated /stabilised by promotion of Lomandra cover.	• Identify nursery capacity for Lomandra production, investigate any know direct seeding technique success, • Assess local Landcare practitioner expertise re: mass planting and establishment techniques, seasonal timing.	**Sub-Reach 4, Sub-Reach 8-9, Sub-Reach 12-15.**

River Condition Issue - & Causes	Restorative Works	Where / How? Strategic	Associated Field Work / Investigations	Specific Sub-Reaches / Properties Identified
	Promoted regeneration	• Areas that retain some remnant vegetation overstorey, natural seedling /sapling recruitment. • Strategically where these areas coincide with areas of geomorphic importance / vulnerability e.g., flood break outs, banks under pressure and or ecological value, e.g., core remnants, structurally complex habitat, rare forest types /species	• Identify sub-reaches with remnant vegetation that has a capacity for promoted regeneration.	Most needed in **Sub-Reach 5 -9**, followed by **Sub-Reach 12-17**
Channel Avulsion / Meander cut-off - Bank erosion / meander migration - Vegetation clearance on floodplain - In-channel sedimentation - Large flood events	Stock exclusion fencing	• Grazing properties where there is potential avulsion risk - tight bends.	• Scope broader endorsement of viable role for fencing maintenance contractor. • Identify number of Grazing properties in project reach lacking exclusion fencing. • Examine relative benefits / bank stability resulting from different types of vegetation cover that result from stock exclusion.	**All priority sub-reaches** where fencing is not in place. Most needed in **Sub-Reach 5 – 9.**
	Intensive revegetation (tube stock planting) of overstorey	• Bends that have a potential avulsion risk. • Planting both the bank and floodplain.	• Identify, map out flood break out points, likely channel migration pressure points. • Develop a recommended riparian ecotone / floodplain revegetation species suite recognising distinction with commonly utilised riparian zone species	Most needed in **Sub-Reach 5 – 9.**
	Other hard engineering works?	• Rock stabilisation of bends that have a potential avulsion risk. • Pile fields at specific bends to avoid rockwork, where possible • Pile fields along avulsion path to increase roughness		Most needed in **Sub-Reach 5, Sub-Reach 7, Sub-Reach 8**

River Condition Issue - & Causes	Restorative Works	Where / How? Strategic	Associated Field Work / Investigations	Specific Sub-Reaches / Properties Identified
Channel Incision / Bank Collapse **- Reduced sediment supply** **- Catchment clearing** **- Peakier flow events** **- Removal of instream structure** **- Reduced channel roughness**	Stabilise toe of bank slopes	• Rock armouring with revegetation. • Sites where further channel incision not primary driver. • Revegetation with Lomandra and emergent macrophyte species where erosion pressure / bank collapse risk less significant /advanced	• Identify specific site characteristics that define strategic location and identify during field work / from reach mapping.	Upper sub-reaches**, Sub-Reach 1, Sub-Reach 4 – Sub-Reach 9**
	Raise stream bed level	• Potential placement of very large material, e.g., boulders on stream bed in nominated locations • Grade control structures at identified high risk / actively incising reach lengths, to change grade of stream bed slope through project reach.	• Conduct flood modelling to examine impact of hypothetical bed level raising to be able to communicate to community stakeholders nature of, or lack of risks, re: increasing flooding, promoting channel avulsion. • Consult landholders and do hydroacoustic bathymetry investigations of nominated risk reaches to identify association between bed depth and bank stability / collapse. • Engineering design of structures to ensure longer term stability	Needs bathymetry data to confirm, but potential headcuts migrating from **Sub-Reach 8** upstream. **Sub-Reach 1, Sub-Reach 5-8.**
	Increase channel roughness	• Establish in channel structure e.g., pile fields. • Reintroduce and anchor large woody debris through project reach. • Revegetate stream banks.	• Need to demonstrate any associated risks to flooding behaviour. Quantifying existing levels of instream structure important justification and for providing baseline. • Anchoring methods for installing instream LWD	**Sub-Reach 12 – Sub-Reach 17**

River Condition Issue - & Causes	Restorative Works	Where / How? Strategic	Associated Field Work / Investigations	Specific Sub-Reaches / Properties Identified
	Rehabilitate catchment condition to deliver less peaky hydrograph	• Large scale works outside project reach. • Primary requirement is increased detention function in contributing catchments to slow down / desynchronise sub catchment run off. • Upper catchment channel and catchment revegetation, including floodplain and levee areas is key. • Installation of farm dams on gullies. • Revegetated and redesign gullies.	• Examine overview status of contributing catchment area rerun off hydrographs, vegetation cover, channel condition, land use to identify generic management prescriptions that could be applied.	**Outside of project reach. Future works**
	Re-establish channel sediment supply	• Not sure if this is an actual driver in the case of the project reach? Contrary i.e., elevated sediment supply is intuitive, though possible instream structures (bridges, dams) are impeding supply to lower catchment?	• Conduct first order examination of sediment supply scenario of upper catchment to see if any obvious impacts on supply levels.	**Outside of project reach. Future works**.
Elevated Sediment / Nutrient Loads Water Quality Decline **- Catchment and stream bank erosion** **- Run off from agricultural and pastoral land use** **- Peakier flow events with**	Channel and catchment revegetation (also see above)	• Within project reach, identification of bank channel areas requiring revegetation also proposed for geomorphic, ecological drivers.	• Conduct vegetation cover, land use, catchment condition assessment of all side catchments contributing to the project reach (completed). • Identify opportunities to mitigate catchment contaminant loads via revegetation, buffer establishment, detention basin construction and/or land use change.	**Sub-Reach 4 -Sub-Reach 9.** **Tributaries/Gullies** mapped that provide large sediment supply.
		• Need assessment of catchment condition / vegetation cover, sediment/nutrient load exporting potential at whole of contributing catchment scale i.e., including all areas upstream of project reach		**Outside of project reach. Future works**

River Condition Issue - & Causes	Restorative Works	Where / How? Strategic	Associated Field Work / Investigations	Specific Sub-Reaches / Properties Identified
greater contaminant load carrying capacity	Land use practice change	• Need assessment at whole of contributing catchment scale (i.e., including all areas upstream of project reach.)	• Preliminary audit of contributing catchment areas within project reach to identify most significant likely contributors to elevated loads (completed). • Develop future work proposal for rapid assessment land use practice audit of entire contributing catchment.	**Outside of project reach. Future works**
	Increase detention function in contributing sub catchments	• Where contributing catchments to the project reach have poor condition /elevated contaminant load characteristics, but also geomorphic features e.g., incised channels, or low grade reaches, bedrock features that could facilitate onstream restorative works, or structure establishment to create detention areas ideally with habitat creation co benefits. • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.	• Spatially define all contributing catchments. Classify in terms of land use / contaminant load risks. Identify channel features that lend toward detention area creation.	**Tributaries/Gullies** mapped that provide large sediment supply (Figure 3-27)
Loss of instream physical habitat **- Catchment and bank vegetation clearing reducing snag supply** **- Snag removal** **- Peakier flow events transporting debris out of reach**	Channel and catchment revegetation (see above)	• Stable reaches with less erosive forces operating. Establish protocol with local vegetation management contractors for receipt of large hard wood trees from clearing operations.	• Canvas willing landholders for receiving snag reinstatement works.	**Sub-Reach 9, Sub-Reach 12-17**
	Reinstatement, anchoring of large woody debris within project reach.	• Deepwater habitat lacking snag features.	• Need to demonstrate any associated risks to flooding behaviour. Quantifying existing levels of instream structure important justification and for providing baseline.	
			• Research established snag anchoring techniques to assure stakeholders of risk management and to identify suitable methods /sites.	

River Condition Issue - & Causes	Restorative Works	Where / How? Strategic	Associated Field Work / Investigations	Specific Sub-Reaches / Properties Identified
Loss of Riparian (& ecotonal) vegetation - Bank and catchment clearing - Grazing stock pressure on banks - Erosion	Revegetation (see above)	• Degraded / cleared banks that have lost natural regenerative capacity (i.e., no remnant overstorey). • Eroded bank areas not requiring more intensive engineered solutions (not as initial works but role post engineering).	• For revegetation beyond primary geomorphic benefits examine landscape context /ecology of broader project reach including existing corridor and remnant network. Identify ecologically strategic revegetation on the basis of promoting greater habitat connectivity, building on existing core remnant. Also consider ecotonal areas (high bank adjoining riparian zone) as areas with key habitat resource provision role for fauna but also geomorphic role re; Flood outbreaks.	**Sub-Reach 9 priority, Sub-Reach 4-8, Sub-Reach 12-17**
		• Sites where revegetation can play greater geomorphic /ecological roles, i.e., channel outbreak distributaries, projected pressure points in channel evolution, breaks in riparian vegetation connectivity.	• Formally capturing the most suited inundation zonation for species used in revegetation would lead to better resource investment use.	
		• It was noted in the field that existing revegetation has had mixed success in terms of the survival of different species at different inundation heights within the channel.		

Table 4-2 Property site-based issues and management measures for discussion

Reach	Issues	Potential Management Measures
1 428 BOATHARBOUR ROAD BOAT HARBOUR		
9	• Off-channel • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation	• Intensive revegetation (tube stock planting) of overstorey • Rehabilitate catchment condition to deliver less peaky hydrograph. • Channel and catchment revegetation (also see above) • Land use practice change
2 18 RICHMOND HILL ROAD RICHMOND HILL		
20	• Loss of Riparian (& ecotonal) vegetation	• Revegetation
3 391 BOATHARBOUR ROAD BOAT HARBOUR		
10	• Off-channel • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
4 424 BOATHARBOUR ROAD BOAT HARBOUR		
9	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of instream physical habitat • Loss of Riparian (& ecotonal) vegetation	• Stock exclusion fencing • Intensive planting understorey Lomandra • Promoted regeneration • Intensive riparian revegetation (tube stock planting) of overstorey • Rock stabilisation of bends that have a potential avulsion risk. • Pile fields at specific bends to avoid rockwork, where possible • Pile fields along avulsion path to increase roughness • Stabilise toe of bank slopes • Raise stream bed level • Increase channel roughness – Reinstatement, anchoring of large woody debris within project reach. • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Catchment revegetation • Land use practice change • Increase detention function in contributing sub catchments
5 211 BOATHARBOUR ROAD BOAT HARBOUR		
13	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of instream physical habitat • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Stock exclusion fencing • Intensive riparian revegetation • Intensive planting understorey Lomandra • Promoted regeneration • Increase channel roughness – Reinstatement, anchoring of large woody debris within project reach. • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Land use practice change • Increase detention function in contributing sub catchments • Catchment revegetation • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
6 379 BOATHARBOUR ROAD BOAT HARBOUR		
11	• Off-channel • Loss of Riparian (& ecotonal) vegetation	• Revegetation of catchment • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.

Reach	Issues	Potential Management Measures
	• Gully development and associated sediment/water quality implications	
7 413 BOATHARBOUR ROAD BOAT HARBOUR		
9	• Off-channel • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation	• Rehabilitate catchment condition to deliver less peaky hydrograph • Catchment revegetation • Land use practice change • Increase detention function in contributing sub catchments
8 127 ELTHAM ROAD BEXHILL		
8	• Loss of Riparian (& ecotonal) vegetation • Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Stock exclusion fencing • Intensive planting understorey Lomandra • Promoted regeneration • Stock exclusion fencing • Intensive riparian revegetation (tube stock planting) of overstorey • Rock stabilisation of bends that have a potential avulsion risk. • Pile fields at specific bends to avoid rockwork, where possible • Pile fields along avulsion path to increase roughness • Stabilise toe of bank slopes • Raise stream bed level • Increase channel roughness • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Catchment revegetation • Land use practice change • Increase detention function in contributing sub catchments • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
9 514 BOATHARBOUR ROAD BOAT HARBOUR		
7	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Stock exclusion fencing • Intensive planting understorey Lomandra • Promoted regeneration • Intensive riparian revegetation (tube stock planting) of overstorey • Rock stabilisation of bends that have a potential avulsion risk. • Pile fields at specific bends to avoid rockwork, where possible • Pile fields along avulsion path to increase roughness • Stabilise toe of bank slopes • Raise stream bed level • Increase channel roughness • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Catchment revegetation • Land use practice change • Increase detention function in contributing sub catchments • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
10 195 CAMERON ROAD MCLEANS RIDGES		
12	• Off-channel • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation	• Rehabilitate catchment condition to deliver less peaky hydrograph • Land use practice change • Increase detention function in contributing sub catchments • Revegetation
11 34 GREENGATE ROAD BEXHILL		
19 & 20	• Loss of Riparian (& ecotonal) vegetation	• Revegetation

Reach	Issues	Potential Management Measures
12 20 BOATHARBOUR ROAD RICHMOND HILL		
19 & 20	• Loss of Riparian (& ecotonal) vegetation	• Revegetation
13 357 BOATHARBOUR ROAD BOAT HARBOUR		
10	• Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Revegetation • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
14 615 COWLONG ROAD ELTHAM		
6/7	• Off-channel • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Intensive riparian revegetation (tube stock planting) of overstorey • Rehabilitate catchment condition to deliver less peaky hydrograph • Catchment revegetation • Land use practice change • Increase detention function in contributing sub catchments • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
15 756 BOATHARBOUR ROAD ELTHAM		
3	• Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Revegetation of riparian zone • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
16 621A BOATHARBOUR ROAD ELTHAM		
7	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Stock exclusion fencing • Intensive planting understorey Lomandra • Promoted regeneration • Intensive riparian revegetation (tube stock planting) of overstorey • Rock stabilisation of bends that have a potential avulsion risk. • Pile fields at specific bends to avoid rockwork, where possible • Pile fields along avulsion path to increase roughness • Stabilise toe of bank slopes • Raise stream bed level • Increase channel roughness • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Catchment revegetation • Land use practice change • Increase detention function in contributing sub catchments • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
17 712 BOATHARBOUR ROAD ELTHAM		
3&4	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline	• Stock exclusion fencing • Intensive revegetation • Intensive planting understorey Lomandra • Stabilise toe of bank slopes • Raise stream bed level • Channel and catchment revegetation (also see above) • Land use practice change • Increase detention function in contributing sub catchments
18 583 BOATHARBOUR ROAD BOAT HARBOUR		
6/7	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off	• Stock exclusion fencing • Intensive planting understorey Lomandra • Promoted regeneration • Intensive riparian revegetation (tube stock planting) of overstorey

Reach	Issues	Potential Management Measures
	• Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Rock stabilisation of bends that have a potential avulsion risk. • Pile fields at specific bends to avoid rockwork, where possible • Pile fields along avulsion path to increase roughness • Stabilise toe of bank slopes • Raise stream bed level • Increase channel roughness • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Catchment revegetation (also see above) • Land use practice change • Increase detention function in contributing sub catchments • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
19 27A PARADISE COURT MCLEANS RIDGES		
12	• Off-channel • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Rehabilitate catchment condition to deliver less peaky hydrograph • Land use practice change • Increase detention function in contributing sub catchments • Catchment revegetation • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
20 644 BOATHARBOUR ROAD ELTHAM		
5, 6/7	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Stock exclusion fencing • Intensive planting understorey Lomandra • Promoted regeneration • Intensive riparian revegetation (tube stock planting) of overstorey • Rock stabilisation of bends that have a potential avulsion risk. • Pile fields at specific bends to avoid rockwork, where possible • Pile fields along avulsion path to increase roughness • Stabilise toe of bank slopes • Raise stream bed level • Increase channel roughness • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Catchment revegetation • Land use practice change • Increase detention function in contributing sub catchments • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
21 46 OSBORNE ROAD BEXHILL		
13, 14, 15	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of instream physical habitat • Loss of Riparian (& ecotonal) vegetation	• Stock exclusion fencing • Intensive riparian revegetation • Intensive planting understorey Lomandra • Promoted regeneration • Increase channel roughness - Reinstatement, anchoring of large woody debris within project reach. • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Land use practice change • Increase detention function in contributing sub catchments • Catchment revegetation (see above)
22 273 BOATHARBOUR ROAD BOAT HARBOUR		
11 & 12	• Bank Erosion and Scalding	• Stock exclusion fencing • Intensive riparian revegetation

Reach	Issues	Potential Management Measures
	• Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of instream physical habitat • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Intensive planting understorey Lomandra • Promoted regeneration • Increase channel roughness - Reinstatement, anchoring of large woody debris within project reach. • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Land use practice change • Increase detention function in contributing sub catchments • Catchment revegetation • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
23 125 MCKINNON ROAD BOAT HARBOUR		
12	• Bank Erosion and Scalding • Channel Avulsion / Meander cut-off • Channel Incision / Bank Collapse • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of instream physical habitat • Loss of Riparian (& ecotonal) vegetation • Gully development and associated sediment/water quality implications	• Stock exclusion fencing • Intensive riparian revegetation • Intensive planting understorey Lomandra • Promoted regeneration • Increase channel roughness - Reinstatement, anchoring of large woody debris within project reach. • Rehabilitate catchment condition to deliver less peaky hydrograph • Re-establish channel sediment supply • Land use practice change • Increase detention function in contributing sub catchments • Catchment revegetation • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.
24 30 RIDGELAND CLOSE BOAT HARBOUR		
13	• Off-channel • Elevated Sediment / Nutrient Loads Water Quality Decline • Loss of Riparian (& ecotonal) vegetation	• Rehabilitate catchment condition to deliver less peaky hydrograph • Land use practice change • Increase detention function in contributing sub catchments • Channel and catchment revegetation • Revegetation of gully riparian zone and source catchment. • On-farm detention basins. • Gully headcut stabilisation works.

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APPENDIX A. FIELD PROFORMAS

RIVER STYLES (STAGE 1 AND 2) FIELD PROFORMAS

Appendix C Table 1 Definitions and measurement procedures for each geoindicator (adapted from Brierley and Fryirs, 2013)

Geoindicator	Definition	Examples of ways to assess each geoindicator
Channel Attributes		
Bank morphology	The shape and character of each bank	• Identification of uniform vertical, uniform graded, faceted, undercut banks. • Identification of signs of bank erosion and channel widening
Instream vegetation structure	The character and density of aquatic and terrestrial vegetation. Linked to the geomorphic structure and flow regime.	• Qualitative rating of the composition and coverage of vegetation on instream geomorphic surfaces.
Woody debris loading	The character and density of woody debris and its relationships to the geomorphic structure and flow regime.	• Qualitative rating of type, alignment, and abundance of woody debris in the channel.
Channel Planform		
Lateral stability	The degree to which the channel can move on the valley floor.	• Identification of channel expansion, bank erosion, migration, and avulsion processes.
Geomorphic unit assemblage	The building blocks of rivers. Each geomorphic unit has a distinct form-process association.	• Analysis of form and sedimentology to interpret processes responsible for formation of different geomorphic units. • Assessment of the juxtaposition and assemblage of units. • Assessment of channel-floodplain connectivity and unit condition (e.g., signs of reworking, dissection, etc.)
Riparian vegetation	The character and density of vegetation in the riparian zone, linked to the geomorphic structure and flow regime.	• Qualitative ranking of composition (native versus exotic), continuity, and structure of vegetation assemblages in the riparian zone.
Bed Character		
Grain size and sorting	The size, distribution, and arrangement of materials stored and transported on the bed.	• Visual estimates of the percent of the bed that comprises different grain size fractions. • Analysis of sediment distributions on different geomorphic units.
Bed stability	Capacity of the channel bed to adjust vertically.	• Interpretation of vertical bed activity via incision or aggradation processes.
Hydraulic Diversity	The character of flow as it passes over the bed.	• Visual surface flow estimates.

Geoindicator	Definition	Examples of ways to assess each geoindicator
Sediment regime	The storage, transfer, and delivery capacity of the reach. Measures the capacity and/or competence of the reach to transport sediment	• Identifying sediment process zone (i.e., source, transfer, accumulation) (Schumm, 1977). • Quantitative measure of sediment transport capacity versus sediment availability to interpret supply vs. transport limited reaches.

Appendix C Table 2 Field proforma used to assess geoindicators and determine geomorphic condition for each of the field sites.

Field Proforma		
1. Identify River Styles	(Valley confinement, planform, geomorphic units, and bed material size)	
2. 'Geo-indicators' to assess River Condition	Qualitative Assessment - Stage 2 of RS Framework	
Geoindicator Type	Questions to Ask for Each Reach of the River Style/reach	Yes/No
Channel Attributes		
Bank Morphology	Are banks eroding in the right places and at the right rate (i.e., with no signs of channel expansion?)	Y/N
Instream vegetation	Is there wood around islands and/or potential for wood recruitment? (wood often induces island development and acts as a forcing agent for pool-run development)	Y/N
Wood loading	Is the instream vegetation structure appropriate?	Y/N
Geomorphic Condition	2+ out of 3 = GOOD 1 out of 3 = MODERATE 0 out of 3 = POOR	GOOD, MODERATE or POOR
Channel Planform		
Lateral Stability	Is the lateral stability of the channel consistent with the sediment texture and channel slope? (No signs of channel degradation such as local widening?) (n/for confined types unless unusual scour has occurred)	Y/N
Geomorphic Unit Assemblage	Is the assemblage, pattern and condition of the instream and floodplain geomorphic units appropriate for the River Style? Are key units present? (i.e., confined types: does the reach have bedrock-induced pools and runs with well-vegetated islands and bedrock outcrops with no signs of deterioration such as infilled pools or extensive sand sheets covering the channel bed? Partly confined/unconfined: planar riffles, runs, pools, point bars, other bars present?)	Y/N
Riparian Vegetation	Are appropriate types and density of riparian vegetation present on the banks and the floodplain?	Y/N
Geomorphic Condition	2+ out of 3 = GOOD 1 out of 3 = MODERATE 0 out of 3 = POOR	GOOD, MODERATE or POOR
Bed Character		

Field Proforma		
Grain Size and Sorting	Is the grain size, sorting and organization of materials in different geomorphic units appropriate for the River Style?	Y/N
Bed Stability	Is the bed vertically stable such that it is not incising or aggrading inappropriately for the channel slope, sediment caliber and sinuosity? (n/a for bedrock bed types unless abnormal sand sheet aggradation has occurred)	Y/N
Hydraulic Diversity	Is there a wide range of roughness characteristics and hydraulic diversity along the reach?	Y/N
Sediment Regime	Is the sediment storage and transport function of the reach appropriate for the catchment position? (i.e., sediment production, transfer, or accumulation zones appropriate for that River Style type)	Y/N
Geomorphic Condition	3+ out of 4 = GOOD 2 out of 4 = MODERATE 0-1 out of 4 = POOR	GOOD, MODERATE or POOR
Overall Geomorphic Condition Ranking	3 x GOOD = GOOD 2xGOOD + 1xMODERATE = GOOD-MODERATE 2xMODERATE + 1xGOOD or 3 x MODERATE or 1xGOOD + 1xMODERATE + 1xPOOR = MODERATE 2xMODERATE + 1xPOOR = MODERATE-POOR 2xPOOR + 1xMODERATE = POOR-MODERATE 3xPOOR = POOR	GOOD, GOOD-MODERATE, MODERATE, MODERATE-POOR, POOR-MODERATE or POOR

AEF007

River Bioassessment Program

HABITAT ASSESSMENT FIELD SHEET

Queensland Government Natural Resources and Mines

SITE NUMBER: [| | | | | |] **SITE NAME:** _____

Date: ___/___/___ **Time (24 hrs):[| | |]** **GPS:** _____ **Project Name:** _____

Habitat Variable	CATEGORY			
	Excellent	**Good**	**Fair**	**Poor**
1. Bottom substrate/available cover	Greater than 50% rubble, gravel, submerged logs, undercut banks or other stable habitat. 20, 19, 18, 17, 16	30-50% rubble, gravel or other stable habitat. Adequate habitat. 15, 14, 13, 12, 11	10-30% rubble, gravel or other stable habitat. Habitat availability less than desirable. 10, 9, 8, 7, 6	Less than 10% rubble, gravel or stable habitat. Lack of habitat is obvious. 5, 4, 3, 2, 1, 0
2. Embeddedness	Gravel, cobble and boulder particles are between 0 & 25% surrounded by fine sediment. 20, 19, 18, 17, 16	Gravel, cobble and boulder particles are between 25% & 50% surrounded by fine sediment. 15, 14, 13, 12, 11	Gravel, cobble and boulder particles are between 50 & 75% surrounded by fine sediment. 10, 9, 8, 7, 6	Gravel, cobble and boulder particles are over 75% surrounded by fine sediment. 5, 4, 3, 2, 1, 0
3. Velocity/depth category	Slow deep (<0.3 m/s & >0.5 m); slow shallow; fast deep; fast shallow; habitats all present. 20, 19, 18, 17, 16	Only 3 of the four habitat categories present (missing riffles or runs receive lower score than missing pools). 15, 14, 13, 12, 11	Only two of the four habitat categories present (missing riffles/runs receive lower score). 10, 9, 8, 7, 6	Dominating by one velocity/depth category (usually pool). 5, 4, 3, 2, 1, 0
4. Channel alteration	Little or no enlargement of islands or point bars and/or no channelisation. 15, 14, 13, 12	Some new increase in bar formation, mostly from coarse gravel; and/or some channelisation present. 11, 10, 9, 8	Moderate deposition of new gravel, coarse sand, on old and new bars; pools partly filled with silt; and/or embankments on both banks. 7, 6, 5, 4	Heavy deposits of fine materials, increased bar development; most pools filled with silt; and/or extensive channelisation. 3, 2, 1, 0
5. Bottom scouring and deposition	Less than 5% of the bottom affected by scouring and deposition. 15, 14, 13, 12	5-30% affected. Scours at constrictions and where grades steepen, some deposition in pools. 11, 10, 9, 8	30-50% affected. Deposits and scours at obstructions and bends. Some deposition in pools. 7, 6, 5, 4	More than 50% of the bottom changing nearly year long. Pools almost absent due to deposition. Only large rocks in riffle exposed. 3, 2, 1, 0

DLI503400RSC.P65 (LM3863) 20/8/98

River Bioassessment Program

HABITAT ASSESSMENT FIELD SHEET cont.

Habitat Variable	CATEGORY			
	Excellent	**Good**	**Fair**	**Poor**
6. Pool/riffle, run/bend ratio. *(Distance between riffles divided by stream width)*	0-7 Variety of habitat. Deep riffles and pools. 15, 14, 13, 12	7-15 Adequate depth in pools and riffles. Bends provide habitat. 11, 10, 9, 8	15-25 Occasional riffle or bend. Bottom contours provide some habitat. 7, 6, 5, 4	>25 Essentially a straight stream. Generally all flat water or shallow riffle. Poor habitat. 3, 2, 1, 0
7. Bank stability	Stable. No evidence of erosion or bank failure. Side slopes generally <30%. Little potential for future problem. 10, 9	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40% on one bank. Slight potential in extreme floods. 8, 7, 6	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60% on some banks. High erosion potential during extreme/high flows. 5, 4, 3	Unstable. Many eroded areas. Side slopes > 60% common. 'Raw' areas frequent along straight sections and bends. 2, 1, 0
8. Bank vegetative stability	Over 80% of the streambank surfaces covered by vegetation or boulders and cobble. 10, 9	50-79% of the streambank surfaces covered by vegetation, gravel or larger material. 8, 7, 6	25-49% of the streambank covered by vegetation, gravel or larger material. 5, 4, 3	Less than 25% of the streambank surfaces covered by vegetation, gravel or larger material. 2, 1, 0
9. Streamside cover	Dominant vegetation is of tree form. 10, 9	Dominant vegetation shrub. 8, 7, 6	Dominant vegetation is grass, sedge, ferns. 5, 4, 3	Over 50% of the streambank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. 2, 1, 0

Column Totals				

Score

○ ○ ○ ○

SIMON (1989, 2007) ADAPTED PROFORMA

SITE DETAILS

Site No: [_____] Catchment: [_____] River/Stream: [_____] Date: [_____] Time: [_____]

Recorders Name: [_____] Photo No: [_____] Water level/Flow: [_____] GPS XY: [_____] AMTD: [_____]

Site Description & Land use:
[_____]

CATCHMENT DETAILS

Sediment	**Mark boxes**		
Zone	1. Source	2. Transfer	3. Sink
Transport	1. Deficient	2. Equilibrium	3. Surplus
Ranking of Sources	1. Bed	2. Catchment	3. Banks
Geology	**1**.1. Sand/Silt Generating	2. Gravel generating	

Hydrology	**No: [_____]**				
Inspection conditions at time of assessment	1. No flow Includes wetlands or intermittent ponds	2. Low flow Normal base-flow water level	3. Moderate flow Higher than normal, some terrestrial vegetation submerged	4. Bankfull	5. Flood Over bankfull flow
Current Form due to	Drought	Flood	Variable flows		
Key geomorphic drivers	Non-regulated			Regulated	
	1. Intermittent flows	2. Low/Mod flows	3. Flood flows	1. Low flows	2. Regulated flows	3. Flood flows

Floodplain Linkages	**No/s: [_____]**			
1. None	2. Wetland Links	3. ORWB Links (Off River Water Bodies)	4. Intermittent	

SITE DETAILS

Anthropogenic Threat	**No/s: [_____]** Frequency of threat per yr: [.....] Severity (1-5 rating, 1 being Extreme): [.....]					
1. Grazing	2. Extractive (mine)	3. Urban residential	4. Rural residential	5. Road	6. Bridge/culvert etc	7. Discharge pipe
8. Forestry	9. Sewerage Effluent	10. Recreation	11. Land Mgt	12. Water extraction	13. Dredging	8. Abstraction
9. Channelization	10. Other					

Existing Local Disturbance	**No/s: [_____]** Frequency of threat per yr: [.....] Severity (1-5 rating, 1 being Extreme): [.....]					
1. Grazing	2. Extractive (mine)	3. Urban residential	4. Rural residential	5. Road	6. Bridge/culvert etc	7. Discharge pipe
8. Forestry	9. Sewerage Effluent	10. Recreation	11. Land Mgt	12. Water extraction	13. Dredging	8. Abstraction
9. Channelization	10. Other					

Waterway type (Describe valley, floodplain, and channel	e.g., Meandering, partly modified channel in a floodplain confined by urban infilling

Dominant Bank material (If more than one, place in order from top to bottom with approximate depth)	**No: [_____]**					
1. Clay (< 2µm)	2. Silt (2µm - 63µm)	3. Sand (63µm – 2mm)	4: Gravel (2mm – 64mm)	5. Cobble (64mm-256mm)	6. Boulders (> 256mm)	6. Bedrock

Hydraulic units	**No/s: [_____]**						
Waterfall	Cascade	Rapid	Riffle	Run	Pool	Dry channel	Floodplain

Channel-stability ranking scheme

Station #_____ **Station Description**_____

Date_____ **Crew**_____ **Samples Taken**_____

Pictures (circle) U/S D/S X-section **Slope**_____ **Pattern:** Meandering Straight Braided

1. Primary bed material

Bedrock	Boulder/Cobble	Gravel	Sand	Silt Clay
0	1	2	3	4

2. Bed/bank protection

Yes	No	(with)	1 bank protected	2 banks
0	1		2	3

3. Degree of incision (Relative ele. Of "normal" low water; floodplain/terrace @ 100%)

0-10%	11-25%	26-50%	51-75%	76-100%
4	3	2	1	0

4. Degree of constriction (Relative decrease in top-bank width from up to downstream)

0-10%	11-25%	26-50%	51-75%	76-100%
0	1	2	3	4

5. Streambank erosion (Each bank)

	None	fluvial	mass wasting (failures)
Left	0	1	2
Right	0	1	2

6. Streambank instability (Percent of each bank failing)

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

7. Established ripirian woody-vegetative cover (Each bank)

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	2	1.5	1	0.5	0
Right	2	1.5	1	0.5	0

8. Occurrence of bank accretion (Percent of each bank with fluvial deposition)

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	2	1.5	1	0.5	0
Right	2	1.5	1	0.5	0

9. Stage of channel evolution

I	II	III	IV	V	VI
0	1	2	4	3	1.5

10. Composition of adjacent side slope (circle)

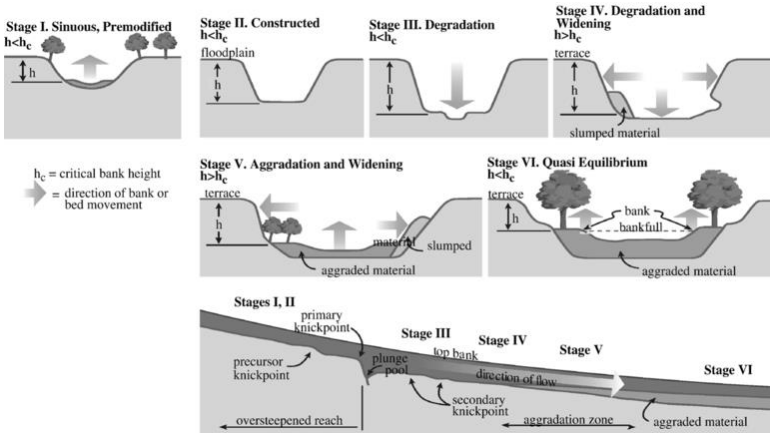
	N/A	Bedrock	Boulders	Gravel-SP	Fines
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

11. Percent of slope (length) contributing sediment

	0-10%	11-25%	26-50%	51-75%	76-100%
Left	0	0.5	1	1.5	2
Right	0	0.5	1	1.5	2

12. Severity of side-slope erosion

	None	Low	Moderate	High
Left	0	0.5	1.5	2
Right	0	0.5	1.5	2



APPENDIX B. METHOD

WATER QUALITY

DATA COLLECTION

At each sub-reach, physicochemical parameters were measured in-situ at the water's surface with a calibrated YSI DSS Pro water quality meter. The following parameters were assessed:

- Temperature (°C).
- Electrical conductivity @ 25°C (µS/cm).
- pH (pH unit).
- Turbidity (NTU); and
- Dissolved oxygen (% saturation and mg/L).

DATA ANALYSIS

Results were compared with the trigger limits determined in the WQO stipulated by DECCW (DECCW, 2006).

HABITAT

BIOASSESSMENT

DATA COLLECTION

Modified State of the River-style and AUSRIVAS habitat descriptions of bed, banks, and riparian zones were completed for each sub-reach. This included descriptions of:

- Macro and microhabitat.
- Bed and bank conditions as well as the identification of the major types of instability (eroding, slumping, and aggrading). Information relating to the slope and shape of the banks.
- Bed substrate composition and embeddedness.
- Adjacent land use and the condition that prevailed at the time of sampling.
- Riparian cover and composition, noting percentage cover of trees, shrubs, grasses/herbs/sedges, and bare areas; and
- Channel alteration, including presence of scouring and/or deposition.

To assist with interpreting habitat classification, the River Bioassessment Program scores (bioassessment scores) (out of 135) were calculated for all sites based on nine AUSRIVAS categories, including: habitat availability (pool/riffle, run/bend ratio); bank stability; streamside cover; bed substrate composition and embeddedness; channel alteration; and presence of scouring and/or deposition. From these scores, an aquatic habitat condition rating was calculated and categorised into poor, fair, good, or excellent habitat conditions.

DATA ANALYSIS

Habitat bioassessment scores were calculated for each sub-reach and mapped in ArcGIS.

HABITAT FEATURE ASSESSMENT

DATA COLLECTION

Each sub-reach was traversed via kayak and the positions of habitat features were recorded using a handheld GPS. The features were selected based on their importance to aquatic species such as fish, turtles, macroinvertebrates, and listed/threatened species. These habitat features included:

- Woody debris
- Undercut banks
- Overhanging vegetation
- Macrophytes
- Root masses
- Lomandra
- Degree of riparian clearing/riparian extent.
- Weed coverage

The longitudinal extent of bankside Lomandra was also recorded by fixing GPS points at the start and end of each unbroken extent. Patches of Lomandra that were <5m in length were recorded as points rather than extent.

DATA ANALYSIS

Habitat feature GPS points were mapped using ArcGIS. The total number of different habitat features were totalled, and each sub-reach was given a habitat diversity score based on the classification in Table 5-1.

Lomandra extent was converted to a percentage of the length of each sub-reach (including both right and left banks). Lomandra points were converted to extents of 2m and included in the calculation. Score classification was based on the Lomandra coverage values displayed in Table 5-2.

The total number of woody debris points were divided by the total area of each sub-reach to give an approximate value for woody debris density. The area of each sub-reach was calculated by creating a 50m buffer around the centre line of the river. Score classification was based on the amount of woody debris values displayed in Table 5 2. The calculated values of Lomandra and woody debris for each sub-reach are displayed in Table 5-4.

The riparian vegetation condition and degree of riparian clearing was based on river bioassessment variable streamside cover categories:

- Dominant vegetation is of tree form: score 9-10.
- Dominant vegetation shrub score: 6-8.
- Dominant vegetation is grass, sedge, ferns: score 3-5.
- Over 50% of streambank with no vegetation: score 0-2.

These categories were converted into broader riparian clearing scores, as outlined in Table 5-5.

The degree of weed coverage was rated by assessing the percent cover of weeds for each sub-reach within the study reach, with scoring based on the values in Table 5-6.

Table 5-1 Habitat diversity scoring system.

No. of habitats present	Score
4	Low
5	Moderate
6	High

Table 5-2 Lomandra coverage scoring system.

Lomandra coverage (%)	Score
≤8.33	Low
≤18.07	Moderate
≤36.2	High

Table 5-3 Woody debris scoring system.

Density of woody debris (/m2)	Score
≤0.00009	Low
≤0.000159	Moderate
≤0.000232	High

Table 5-4 Calculated Lomandra coverage and woody debris values for each sub-reach.

Site	Lomandra coverage	Woody debris
Sub-Reach 1	10.7	0.000079
Sub-Reach 2	33.3	0.000135
Sub-Reach 3	36.2	0.000192
Sub-Reach 4	7.4	0.000227
Sub-Reach 5	18.1	0.000204
Sub-Reach 6 & 7	16.2	0.000109
Sub-Reach 8	5.1	0.00006
Sub-Reach 9	0	0.000065
Sub-Reach 10	5.8	0.000108
Sub-Reach 11	13.6	0.000116
Sub-Reach 12	0.6	0.000118

Site	Lomandra coverage	Woody debris
Sub-Reach 13	2.6	0.000112
Sub-Reach 14	0.1	0.00009
Sub-Reach 15	0.3	0.000036
Sub-Reach 16	24.1	0.000085
Sub-Reach 17	22.5	0.000147
Sub-Reach 18	5.6	0.000206
Sub-Reach 19	9.5	0.000232
Sub-Reach 20	8.3	0.000203

Table 5-5 Riparian clearing scoring system.

River Bioassessment Variable Streamside Cover Score	Score
0-6	High riparian clearing (poor quality)
7-8	Moderate riparian clearing
9-10	Low riparian clearing (good quality)

Table 5-6 Weed coverage scoring system.

% Cover of Weeds in Sub-Reach	Score
0-20%	Low
21-30%	Moderate
>30%	High

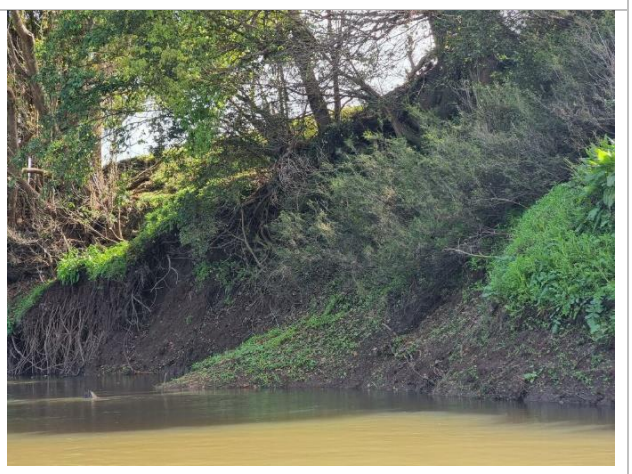
APPENDIX C. SITE PHOTOGRAPHS

SUB-REACH 1

This photo shows a developing gully, with headward erosive processes, incising with head cuts.

This picture shows bank toe cracking and slumping. This is evidence of incision.

As seen above, potential head cut or construction is seen, with an increase in velocity comparatively.



The right bank is seen eroded here, with evidence of slumping and no vegetation seen on the left bank.

A gully is seen here, with headward erosion, avulsion linkup point, and evidence of grazing.

This photo illustrates bank erosion, slumping. Potential livestock trail.

SUB-REACH 2

	
This photo shows bank toe erosion and slumping.	Bank slumping prevalent in this photo.
	
Island establishment seen here, as well as, toe scour, notches with potential gully development, and channel widening.	The channel is seen to widen here with toe scour exposing tree roots. Potential slumping.
	
This photo shows the bank has collapsed over time subjected to scour processes.	Undercutting of the banks and bank scour are some of the erosive processes seen here.

SUB-REACH 3

	
This photo shows the slumping bank and mass tree root exposure leading to tree collapse.	This shows potential livestock trail, leading to ground cover removal in restricted areas, and bank scour.
	
This photo shows increased in-stream diversity; log jams, run and riffles. Toe scour also seen in the mid to left-handed side of the photo.	This photo shows increased in-stream diversity; log jams, run and riffles. Toe scour also seen.
	
This photo illustrates bank cracking, toe slump, and evidence of incision was observed in the field.	Scour of bench feature is seen here. Potential shrink-swell from clayey plastic soils, which can reduce bank stability, especially if intense grazing exists.

SUB-REACH 4

Bank scour is seen here. Potential undercutting present.

This photo illustrates toe scour.

This photo illustrates toe scour.

This photo illustrates toe scour.

This photo illustrates toe scour.

This photo illustrates toe scour.

SUB-REACH 5

This photo illustrates major bank erosion, exposure bank wall and potential avulsion.

Bank scour and failure is seen here.

Bank scour and failure is seen here. Large tree root exposed, reducing bank stability.

Bank scour and collapse is seen here.

Bank scour and collapse is seen here.

This photo illustrates bank cracking and undercutting.

SUB-REACH 6 AND SUB-REACH 7

	
Consistent bank failures seen across these reaches.	This photo shows active scour processes on left bank.
	
Reduced riparian vegetation and bank slumping is seen here.	Evidence of historical bank collapse and currently bank exposed, resulting in vulnerability to current erosive processes.
	
Bank slumping and undercutting is seen here.	Bank erosion is seen here. Evidence of grazing and well-used livestock/quad/4WD trail.

	
Historical bank failure, with active bank scour and decreased amounts of large trees on riparian zone.	Bank collapse, with active toe erosion and decreased amounts of large trees on riparian zone.

SUB-REACH 8

	
Reduced riparian vegetation and bank failures is seen here. Potential bedrock-controlled riverbed.	Reduced riparian vegetation and bank failures is seen here. Potential bedrock-controlled riverbed.
	
Undercut banks is seen here.	This photo shows bank failures associated with flow from the tributary channel joining.
	
Reduced riparian vegetation and bank slumping is seen here.	Reduced riparian vegetation and some bank slumping is seen here. Less slumping comparatively to the photo on the left.

SUB-REACH 9

	
Reduced riparian vegetation and bank slumping is seen here.	Reduced riparian vegetation and bank slumping and bench is seen here. Potential livestock/quad bike trail.
	
Reduced riparian vegetation and predominate tow scour.	Reduced riparian vegetation and bank slumping is seen here.
	
This photo shows bank slumping.	Strong toe scour is seen here.

SUB-REACH 10

	
Bank scour is seen here.	Reduced riparian vegetation and bank failures is seen here.
	
Reduced riparian vegetation and bank failures is seen here. Potential livestock trail.	Reduced riparian vegetation and bank failures is seen here.
	
Bank failures seen here.	Scour throughout bend is seen here.

SUB-REACH 11

	
This photo shows toe and bank scour.	This photo shows toe and bank scour.
	
Flood debris is seen here. Potentially exposed underneath debris.	This photo shows a perched tributary, flow blocked by large woody debris.
	
Flood debris is seen here, along with bank scour.	Flood debris is seen here, along with bank scour.

SUB-REACH 12

	
Toe failure and scour is seen here.	Toe failure and scour is seen here.
	
Headward eroding tributary with toe scour is seen here.	Bank scour is seen here.
	
Scour throughout bend is seen here.	This photo shows bank scour.

SUB-REACH 13

	
Reduced riparian vegetation and bank scour and failures is seen here.	Reduced riparian vegetation and bank scour and failures is seen here.
	
Reduced riparian vegetation and bank scour is seen here.	Reduced riparian vegetation and some bank slumping is seen here.
	
This photo shows some scour and evidence of replanting.	Consistent bank failures throughout the bend are seen here.

SUB-REACH 14

	
This photo shows bedrock step. Part of bank exposed, increased ground cover comparatively.	Bank scour and failure is seen here. Water quality measurement point.
	
Exposed bank is seen here.	Potential bank undercutting. Habitat creation; shade from overhanging vegetation and woody debris. Strong fringing zone.
	
Bank scour and failure is seen here.	Reduced riparian vegetation and toe scour is seen here.

SUB-REACH 15

This photo illustrates bank slump and reduced riparian zone vegetation.

This photo illustrates bank slump and reduced riparian zone vegetation.

Stronger fringing zone comparatively to other sections of the reach. Increased presence of native vegetation on fringing zones. Bank scour and slump is seen.

No trees present on riparian zones, some bank slumping is seen here. Strong evidence of grazing.

This photo shows bank scour and failure. Large tree roots have been exposed and reduce bank stability.

Evidence of livestock trail is seen here. Potentially sediment point source.

SUB-REACH 16

	
Potential avulsion location is seen here.	Potential avulsion location is seen here.
	
Potential avulsion location is seen here.	This photo shows minor toe scour. Increased large vegetation on riparian zone.
	
This photo shows minor toe scour, parts increasing to major. Increased large vegetation on riparian zone and evidence of replanting.	Island establishment seen here, as well as, toe scour, notches with potential gully development, and channel widening.

SUB-REACH 17

	
Toe erosion is seen here.	Toe erosion is seen here.
	
Toe erosion is seen here.	Toe erosion is seen here, bank gouging seen limiting tree stability.
	
This photo shows toe erosion and bank slumping	Increased large vegetation of riparian zones, woody debris observed.

SUB-REACH 18

	
Bank scour is seen here, with potential bank undercutting.	Bank scour is seen here, with potential bank undercutting in parts.
	
This photo illustrates bank failures and exposed large tree roots.	This photo illustrates bank failures and exposed large tree roots, with potential for bank undercutting.
	
Reduced riparian vegetation and bank slumping is seen here.	Reduced riparian vegetation and bank slumping is seen here. Evidence of grazing

SUB-REACH 19

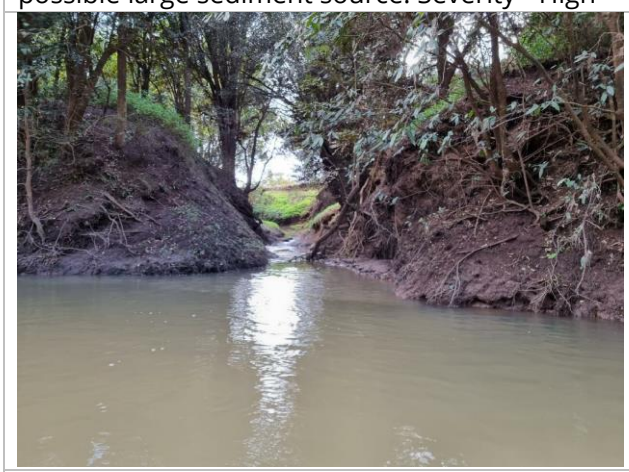
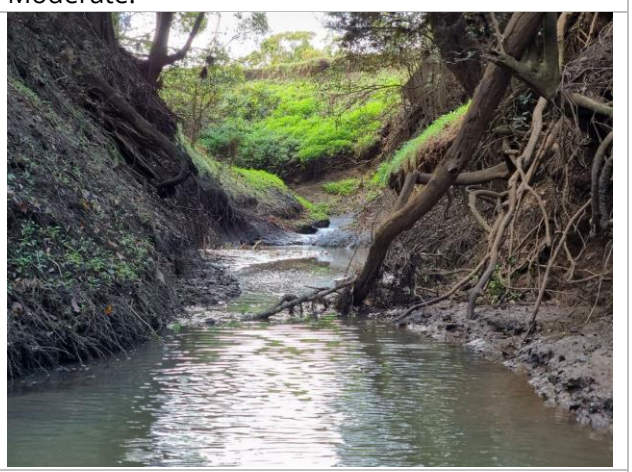
	
Undercut banks is seen here.	This photo shows toe erosion and some loss of tree stability.
	
Undercut banks is seen here.	Undercut banks is seen here.
	
This photo shows the bank has already collapsed where there is no vegetation.	Some scour is seen here, with presence of some large trees on riparian zone.

SUB-REACH 20

	
Bridge pier is seen here. Changes to velocities and consequential changes to depositional patterns. Some bank failure seen, as water is pushed around pier.	Bridge pier is seen here. Changes to velocities and consequential changes to depositional patterns. Some bank failure seen, as water is pushed around pier.
	
Some overhanging vegetation is seen on fringing zone, with undercut banks.	Some overhanging vegetation is seen on fringing zone, with undercut banks.
	
This photo shows increased vegetation comparatively to other sections of the reach. Strong presence of undercut banks.	This photo shows increased vegetation comparatively to other sections of the reach. Strong presence of undercut banks reducing tree stability in some parts.

GULLIES AND TRIBUTARY CONFLUENCES

	
1 – Reach 1, Gully headward eroding, incising with headcuts. Severity – Moderate.	**1**
	
2 – Reach 1, gully, headward erosion, avulsion linkup point. Severity – Low.	**2**–
	
3 – Reach 1, gully, headward erosion, well vegetated at confluence, Severity - Moderate	**3**

	
4 – Reach 3, headward erosion, moderate catchment, sediment deposition, Severity - High	**4** – Reach 3, gully headcuts
	
5 – Reach 7, Large Trib/Gully input, landowner Gary said it has high flow during big events, possible large sediment source. Severity - High	**7** – Reach 7, Meander cut-off and gully. Lots of headcuts in channel. Erosion. Severity – Moderate.
	
8 – Reach 8, Gully tributarys, headward eroding with headcuts, sediment input. Severity - High	**8**

	
9 – Reach 8, Incised Tributary, sediment source. Severity – High.	**9**
	
10 - Reach 9, Tributary with headcuts. Severity – Moderate.	**10**
	
12 - Reach 10, tributary with headcuts, incising/headward eroding. Severity - High	**12**

	
12	**13** – Reach 12, eroding trib. Severity - High
	
14 - Reach 12, headward eroding trib with toe scour. Severity - High	**14**
	
15 - Reach 13, headward eroding trib with bank failures, large sediment input. Severity – High	**15**

	
15	**15**
	
16 - Reach 18, eroding trib with flood debris. Severity - Low	**16**
	
17- Reach 19, headward eroding trib with exposed bedrock	

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